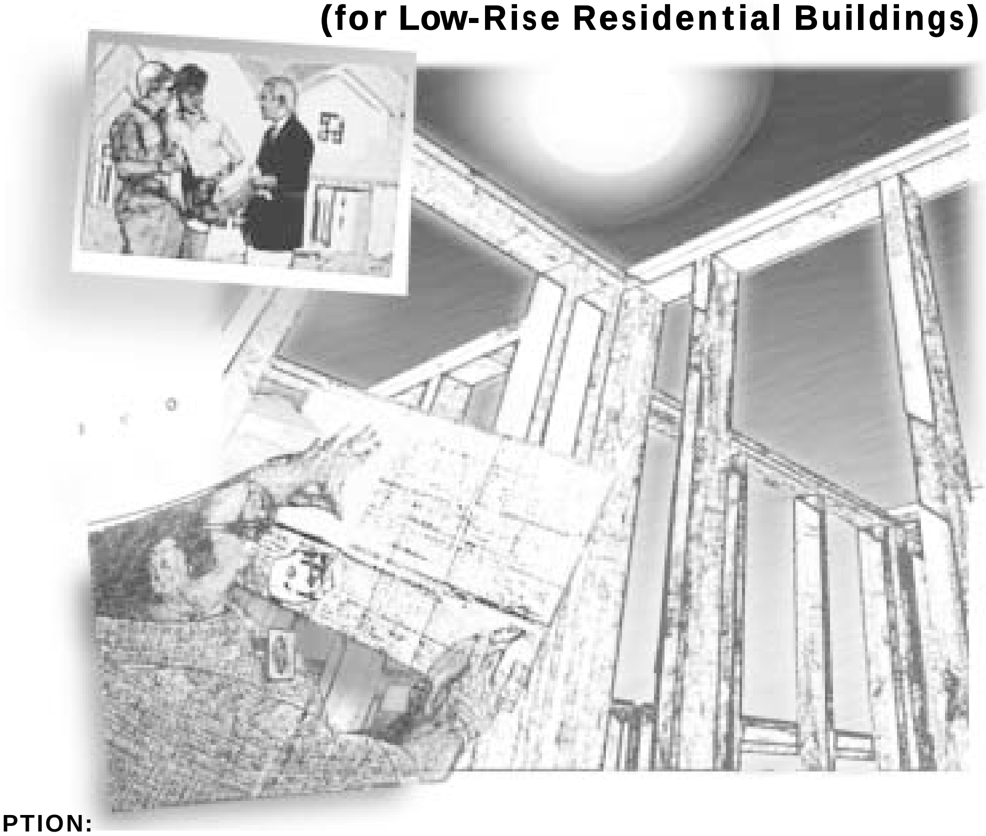
RESIDENTIAL MANUAL

for Compliance with the

2001 ENERGY Efficiency Standards

(for Low-Rise Residential Buildings)



EXCEPTION:
Building energy efficiency standards compliance documentation submitted prior to June 1, 2001 using the Multiple Orientation Alternative of Section 151(c), shall be used to determine compliance through December 31, 2001.

Effective Date June 1, 2001

CALIFORNIA ENERGY COMMISSION

COMMISSION APPROVED MANUAL

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California Energy Commission
Residential Manual

for compliance with the

2001
Energy Efficiency Standards for
Low-Rise Residential Buildings

Energy Commission Publication No. P 400-01-022

This Residential Manual was approved by the California Energy Commission at its September 5, 2001 Business Meeting. The Energy Efficiency Standards were adopted by the California Energy Commission at its April 4, 2001 Business Meeting. The standards are revisions to the Title 24 Building Energy Efficiency Standards (California Code of Regulations, Title 24, Part 6 and the Administrative Regulations, Title 24, Part 1).

September 5, 2001

Acknowledgments

Efficiency Standards Committee

Commissioner Robert Pernell, Presiding Member

Commissioner Arthur H. Rosenfeld, Ph.D., Associate Member

Principal Authors/Editors

The Residential Manual (*Manual*) has evolved over the years with contributions from many persons along the way. The *2001 Manual* was adapted from earlier versions in response to a mandate by the California legislature (Assembly Bill 970). This most recent version was edited and produced by Eley Associates. Charles Eley wrote much of the new material and served as the technical editor. Anamika Prasad provided coordination, graphics, and document production. Content was contributed by, among others, Ken Nittler, Dee Anne Ross, Jonathan Leber, Bill Pennington, Nelson Pena, Tav Commins, and John Eash.

A number of individuals reviewed drafts of the manual and offered useful and constructive comments, including Doug Beaman, Lance DeLaura, Martyn Dodd, Gary Farber, Mike Gabel, Bill Lilly, Bill Mattinson, Bob Pond, John Proctor, Patrick Splitt, Nehemiah Stone, and Dave Ware.

Many others contributed helpful suggestions, comments and criticism. The list is so long that it is impossible to acknowledge everyone. However, their assistance is greatly appreciated.

In spite of all our efforts, omissions and errors are certain to occur. These, of course, are attributed to the authors alone. If a *Manual* user discovers an error or has a suggestion, we ask that it be brought to the attention of the Energy Efficiency Hotline. They can be reached at 1-800-772-3300 (California only) or 916-654-5106.

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1 Introduction

This *Manual* explains the California energy efficiency standards for low-rise residential buildings (*Standard*). The *Manual* is organized in eight chapters and supported by several appendices. This chapter is an introduction and discusses:

- Purpose and Organization of this Manual
- Summary of Recent Changes
- Background
- Introduction to the Residential Standards
- Code Decisions: Case Studies
- Where To Get Help

More information is available at www.energy.ca.gov/title24.

1.1 Purpose and Organization of this Manual

The purpose of this *Manual* is to explain clearly how to comply with and enforce the California energy efficiency standards for residential buildings. The *Manual* is written as both a reference and an instructional guide. It can be used by architects, builders, building owners, designers, energy consultants, enforcement agency personnel, engineers, mechanical contractors and others directly or indirectly involved in the design and construction of residential buildings. “Section” refers to a section in this *Manual* while sections from the *Standard* are represented by “§”.

Portions of the *Manual* focus on improving comfort through construction quality. For instance, Chapter 2 includes diagrams and guidelines for HVAC systems and ducts, including graphic representations of well-constructed duct systems. Chapter 4 includes diagnostic testing procedures for duct leakage, envelope infiltration, and procedures for HVAC system design and installation.

The Chapters

The *Manual* is organized into eight chapters, each of which covers an important topic, or set of topics, regarding energy compliance and energy conservation in residential buildings. There are also several appendices and an extensive glossary.

- *Chapter 1 Introduction* – serves as an overview of the *Standards*. It explains how the *Standards* apply to various building occupancies and highlights key aspects of compliance.
- *Chapter 2 Mandatory Measures* – discusses the mandatory requirements relating to insulation levels, infiltration controls, HVAC and plumbing systems, lighting and appliance features.
- *Chapter 3 Prescriptive Packages* – presents a detailed explanation of how to comply using the prescriptive method; an example of prescriptive compliance documentation; and a listing of the prescriptive package requirements for all 16 climate zones.

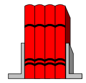
- *Chapter 4 Compliance Through Quality Construction* – details the compliance process using low leakage ducts, reduced building envelope infiltration, and tuned HVAC equipment. These compliance options require installer certification, field verification, and diagnostic testing by a certified HERS rater.
- *Chapter 5 Computer Method* – details the compliance process using Approved Computer Methods; outlines computer modeling guidelines and restricted inputs; and illustrates computer compliance documentation.
- *Chapter 6 Water Heating* – covers energy use, calculations, and compliance documentation for water heating.
- *Chapter 7 Additions and Alterations* – explains compliance for additions and alterations using the prescriptive and the performance approaches.
- *Chapter 8 Special Compliance Topics* – addresses the application of the *Standards* for multi-family buildings, mixed occupancy buildings, subdivision master plans, wood heat, log homes, solar energy systems, zonal control, and hydronic space heating.

The *Manual* is supported by 12 appendices as described below:

- *Appendix A* – Compliance Forms
- *Appendix B* – Materials Reference
- *Appendix C* – California Design Location Data
- *Appendix D* – California Climate Zone Descriptions
- *Appendix E* – List of Publications
- *Appendix F* – List of Approved Computer Programs
- *Appendix G* – Glossary and Explanation of Key Terms
- *Appendix H* – Construction Assemblies
- *Appendix I* – Framing Calculations / Tables / Forms
- *Appendix J* – Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems
- *Appendix K* – Procedures for HVAC System Design and Installation
- *Appendix L* – Procedures for Determining Required Refrigerant Charge and Adequate Airflow for Split System Space Cooling Systems without Thermostatic Expansion Valves

Graphic Icons are used throughout this *Manual* to provide a key to the type of information that is presented and whom it is intended for. The following table describes these icons.

Table 1-1 – Icons Used in Document

	Relevant language (in italics) from the 2001 *Energy Efficiency Standards*		Examples and newsletter excerpts
	Explanations and other direction for the energy consultant and plan checker		General information and concepts
	Explanations and other direction for the builder		Information about how products or materials use and conserve energy
	Explanations and other direction for the inspector		Tools for improving the quality of construction to increase comfort and customer satisfaction and to reduce callbacks and liability

1.2 Summary of Recent Changes

This section describes recent events in California and how the *Standards* have changed in response to these events.

1.2.1 California's Energy Crisis and Assembly Bill 970

In the summer of 2000, California experienced rolling blackouts in the San Francisco Bay area, and electricity bills in San Diego that went up by 200-300%. These events signaled the beginning of an energy crisis that continued into 2001 with rolling blackouts becoming a common occurrence throughout the state. High energy prices depleted the state surplus and caused California's largest utility to file Chapter 11 bankruptcy. At the date of this writing, the State's electrical system continues to be vulnerable to increasing electricity demand, generation supply shortages, transmission constraints, and extremely high wholesale electricity costs caused by an unstable market.

Assembly Bill 970

At the close of the 2000 legislative session, the Legislature responded to the crisis by passing AB 970, an urgency statute that became effective when the Governor signed it on September 6, 2000. The statute, known as the California Energy and Reliability Act of 2000, found that there has been significant growth in the demand for electricity and that new power plant construction and energy conservation have seriously lagged. The act provides a balanced response by providing significant investment in conservation and demand-side management programs. In particular, AB 970 added Section 25553 to the Warren Alquist Act, as follows:

> *Notwithstanding any other provision of law, on or before 120 days after the effective date of this section or on the earliest feasible date thereafter, the Commission shall . . (b) Adopt and implement updated and cost-effective standards pursuant to Section 25402 to ensure the maximum feasible reductions in wasteful, uneconomic, inefficient, or unnecessary consumption of electricity.*

In response to AB 970, the Commission conducted an emergency rulemaking to develop amendments to the *Standards*, which were adopted by the Commission on January 3, 2001 (119 days after AB 970 was signed by the Governor). The AB 970 amendments to the *Standards* focused on reducing peak electricity consumption and demand in the shortest time possible. For consideration in the AB 970 rulemaking, measures had to have the following characteristics:

- Substantial information was already available regarding their benefits and costs;
- Specifications and eligibility criteria could be developed quickly within the time the Legislature allotted; and
- The industry would be able to incorporate the changes on an emergency basis without disruption to construction practice.

The Worsening Situation

Since AB 970 was passed by the Legislature and the 2001 *Standards* were adopted, the reliability of California s electricity system has continued to deteriorate. In his January 2001 State of the State message, the Governor placed highest priority on actions to address what he termed the electricity nightmare. He included the following points in his message:

“Electricity is a basic necessity of life. It is the very fuel which powers our high-tech economy. A dysfunctional energy market is threatening to disrupt people’s lives and damage our economy. It has resulted in skyrocketing prices and an unreliable supply of electricity, causing the average price per megawatt hour to increase by 900%, compared to last year. By reducing peak demand, we can reduce the price; avoid shortages; and lower energy bills.”

In January 2001, power plant outages led to inadequate electricity supplies in California, causing multiple Stage 3 alerts and rolling blackouts in Northern California. The cost of natural gas also has rapidly increased during this period.

The Commission is continuing to update the *Standards* to respond to the energy crisis. Additional enhancements and improvements are being planned for the next update, to be adopted in about 2003 and take effect in 2005.

1.2.2 Assembly Bill 970 Changes

This section summarizes the 2001 changes to the low-rise residential standards that were adopted as part of the AB 970 emergency rulemaking. The changes include additions to the base prescriptive requirements for: duct sealing; air conditioner calibration and testing; radiant barriers in attics; and improved fenestration. Most of these new requirements only apply in hot climates where air conditioning energy contributes significantly to California’s summer electricity peak. In addition to the fundamental changes in the base prescriptive requirements, additional compliance options were added for cool roofs and an alternative package was provided to enable compliance with the *Standards* without the need for verification or diagnostic testing by a HERS rater.

Changes to Alternative Component Package D

Alternative Component Package D contains the basic prescriptive requirements for low-rise residential buildings and several significant changes were made, including new requirements for radiant barriers, duct sealing and air conditioner efficiency improvements. In addition, the fenestration criteria were made more stringent in many climates. With the exception of duct sealing, the new requirements apply only to the hotter California climates, which contribute most to the summer electricity demand. The changes are summarized in the following table for each of the climates. More detail is provided in the bullets that follow and later in the *Manual*.

Table 1-2 – Summary of Changes to Package D

Climate Zone	Radiant Barrier	Maximum Fenestration U-factor	Maximum Fenestration SHGC	Duct Sealing*	Charge and Airflow Testing or TXV*
1	--	--	--	Required	--
2	Required	0.65	0.40	Required	Required
3	--	--	--	Required	--
4	Required	0.75	0.40	Required	--
5	--	--	--	Required	--
6	--	--	--	Required	--
7	--	0.75	0.40	Required	--
8	Required	0.75	0.40	Required	Required
9	Required	0.75	0.40	Required	Required
10	Required	0.65	0.40	Required	Required
11	Required	0.65	0.40	Required	Required
12	Required	0.65	0.40	Required	Required
13	Required	0.65	0.40	Required	Required
14	Required	0.65	0.40	Required	Required
15	Required	0.65	0.40	Required	Required
16	--	--	--	Required	--

“--" means no change from current requirements

* Duct sealing, charge and airflow testing, and thermostatic expansion valve (TXV) require diagnostic testing and/or field verification by a certified HERS rater.

Other Package D requirements remain unchanged.

Radiant Barriers

Radiant barriers, which were previously a compliance option, are required in climate zones 2, 4, and 8 through 15. Radiant barriers are shiny metallic surfaces that are applied to the roof (and to end walls at attic conditions). The barrier reduces heat flow between the solar-heated roofing and the ceiling, thus lowering interior temperatures and temperatures in the attic or in enclosed rafter spaces between the roof and the ceiling. This reduces air conditioning energy, both because the cooling load is lower for the conditioned space and the air distribution ducts are more efficient because of the lower attic temperature. Qualifying radiant barriers must have an emittance of 0.05 or less and be certified by the Bureau of Home Furnishings. More details about the installation requirements for radiant barriers are presented in Section 3.4 under Prescriptive Packages.

Solar Heat Gain Coefficient

The *Standards* reduce solar heat gain through windows and skylights in climate zones 2, 4, and 7 through 15, again the climates where cooling loads and peak demand for electricity are the most significant. The required solar heat gain coefficient (SHGC) is reduced to 0.40 in these locations for all orientations. Previously, the 0.40 SHGC requirements only applied to limited climate zones and/or orientations. The new SHGC requirement will typically be achieved with “low solar, low emissivity” glass, also known as “spectrally selective” glass. Fenestration product performance for Prescriptive compliance in these climate zones must be documented using U-factor and SHGC data provided by the National Fenestration Rating Council (NFRC).

Diagnostic Testing of Air Distribution Ducts

Diagnostic testing of air distribution ducts is required in every climate zone as part of the AB 970 changes to Package D. All ducts must be tested, and sealed if necessary, so that the leakage is less than or equal to 6% of the fan volume, e.g. if the fan delivers 1,000 cfm, the leakage cannot exceed 60 cfm. Up to 30% of heating and cooling energy can be lost through poorly installed or poorly sealed ducts so this is very cost effective measure. Prior to the AB 970 changes, diagnostic testing of ducts was a compliance option; now it is a requirement. The testing must be performed by a certified HERS rater. The testing is a prescriptive requirement, which can be avoided with the performance method. As an alternative to duct sealing and testing, builders can install higher efficiency HVAC equipment and higher performance glazing; the alternative requirements vary by climate zone. See Alternative to Package D below.

The mandatory duct construction requirements are changed to prohibit the use of building cavities as ducts. Also, cloth back rubber adhesive duct tape, if used, must be used in combination with mastic and drawbands. See more below on changes to mandatory measures.

Refrigerant Charge and Air Flow Measurement or Thermostatic Expansion Valves (TXVs)

For residential air conditioners to operate at optimum efficiency, the refrigerant charge and the airflow across the cooling coil must be carefully adjusted in the field at the time of installation. This is true for both air conditioners and heat pumps, when operating in a cooling mode. Improper charge and airflow can cause other problems as well. Excessive charge can cause premature compressor failure, while insufficient charge allows compressors to overheat. Very low airflow can result in icing of the coil and cause compressor failure. To help avoid these problems and provide for optimum energy performance, the AB 970 changes require one of two options. Either a technician must verify that the equipment has the correct airflow and refrigerant charge, or a thermostatic expansion valve (TXV) must be installed for the air conditioner. Either must be verified by a HERS rater. These requirements apply to split system air conditioners and heat pumps, but not to packaged air conditioners.

Fenestration in Additions and Alterations

Fenestration installed in residential alterations and additions of up to 100 ft² must meet the package D requirements for SHGC (0.40 in the hot climates) and the fenestration U-factor must be less than or equal to 0.75. These requirements apply when the prescriptive method of compliance is used. If fenestration is being repaired or replaced, but not in conjunction with a building alteration, it is exempt from the 0.75 U-factor and Package D SHGC requirements.

Alternative to Package D

Package D requires that air distribution ducts be tested and verified by a HERS rater. A HERS rater must also verify the refrigerant charge and airflow across the evaporator coils. An alternative set of requirements offers an option which provides equivalent energy savings, but does not require diagnostic testing and field verification by a certified HERS rater. The alternative combination of features results in equal or less energy and it does not increase electric demand. This is achieved by requiring more energy efficient space conditioning equipment and fenestration. The Alternative to Package D requirements are shown in Table 1-3. All the other requirements of Package D must still be met.

Table 1-3 – Alternative to Package D (Alternative to Duct Sealing and TXV Requirements)

Climate Zone	Maximum Fenestration U-factor	Maximum Fenestration SHGC	Equipment Efficiency
1	0.55	--	90% AFUE
2	0.40	0.35	--
3	0.55	--	--
4	0.40	0.35	--
5	0.55	--	--
6	0.55	--	--
7	0.40	0.35	--
8	0.40	0.35	--
9	0.40	0.35	11 SEER
10	0.40	0.35	11 SEER
11	0.40	0.35	12 SEER
12	0.40	0.35	11 SEER
13	0.40	0.35	12 SEER
14	0.40	0.30	12 SEER
15	0.40	0.30	13 SEER
16	0.55	--	90% AFUE

Compliance Modeling Changes

There are several other changes that have an impact on the stringency of the *Standards*.

Interior Shading Devices

Credit for interior shading is eliminated in all compliance approaches. Prior to the AB 970 changes, it was possible to comply with the solar shading requirements by installing opaque roller shades and/or blinds. In 1998, the interior shading credit was removed from the prescriptive compliance and the roller shade credit was reduced to a level equivalent to blinds. The AB 970 changes entirely eliminate the compliance credit for either roller shades or mini-blinds.

Central Air Conditioner Assumptions

The modeling assumptions for air conditioner system efficiency are changed to reflect typical performance, based on findings of field studies on standard practice airflow, refrigerant charge and fan wattage. The efficiency is also adjusted for outdoor temperature effects based on the typical operating temperatures found in California climate zones.

New Compliance Options

Cool Roofs

Cool roofs are a new compliance option added with the AB 970 changes. To qualify as a cool roof, the roof surface must have both a solar reflectance greater than 0.70 and a emissivity greater than 0.75. The solar reflectance criterion is 0.40 for clay and concrete tile roofs. The solar reflectance criterion applies to the initial reflectance of the manufactured product and does not account for aging. Manufacturer’s literature or test reports can be used to verify cool roof products, but after January 1, 2003, all cool roof products qualifying for this credit are required to be tested and labeled according to procedures established by the Cool Roof Rating Council.

Multi-Family Ducts

The credit for ACCA Manual D duct design is expanded to multi-family buildings. This option was previously limited to single-family dwelling units.

Note: The prescriptive requirements for duct sealing (maximum leakage of 6%) apply to multi-family buildings as well as single-family homes.

Mandatory and Procedural Changes

Fenestration Default Table

Labels used in the default fenestration U-factor tables are changed to more accurately reflect what is meant. In particular, the descriptors “uncoated” and “tinted” in *Standards*

Table 1-E are changed to “clear” and “tinted.” Actual values in the table remain unchanged.

Duct Construction

The AB 970 changes also expand the mandatory measures for air distribution ducts.

- Building cavities, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct may not be used for conveying conditioned air including return air and supply air.
- Such building cavities and support platforms may contain ducts, but ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross sectional area.
- Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Field Verification

The AB 970 changes give authority to the HERS rater for selecting a sample of homes for diagnostic testing. This will avoid delays in completing the necessary field verification and compliance documentation.

Multiple Orientation Alternative

Compliance with the energy standards is sensitive to orientation, especially in climates with significant cooling loads. If a tract home model complies in the four cardinal orientations (north, east, south and west), the *Standards* accept this as evidence that the home complies in any orientation. This multiple orientation option is offered as an exception to §151 (a) and (b).

Prior to the AB 970 changes, a builder could modify solar shading for the house in different orientations in order to achieve compliance. Typically, exterior sunscreens or roller shades (when they were allowed as a compliance option) were added to the windows on the west and perhaps the south sides of the house. To the building inspector, each house would look a little different. Some would have sunscreens on the back of the house, if the back faced west. Some would have sunscreens on the front if the front faced west, etc.

Advances in glazing technologies allow compliance with the low solar heat gain coefficients without the need for interior or exterior shading devices, so the AB 970 changes eliminate the option to relocate sunscreens or to modify shading by orientation. Tract homes that use the multiple orientation option must demonstrate compliance for the same set of features in each of the cardinal orientations. It is no longer possible to move shading devices from one orientation to another to achieve compliance.

Packages A, B and C Changes

Packages A and B are deleted as compliance options, since they are rarely used. To avoid confusion, Packages C and D are not renamed. The new and updated features of Package D are cost effective, and are included in Package C requirements as well. These requirements include the lower SHGC values for fenestration, duct diagnostic testing, and refrigerant charge and airflow testing (or TXV).

1.3 Background

1.3.1 Legal Requirements – The Warren Alquist Act

All new buildings in California must meet the standards contained in Title 24, Part 6 of the California Code of Regulations. All new construction must comply with the *Standards* in effect on the date a building permit application is made (not when the building permit is issued).

Section 25402 of the Public Resources Code directs the California Energy Commission to:

> *"Prescribe, by regulation. . . building design and construction standards which increase the efficiency in the use of energy for new residential and new nonresidential buildings.*

Applicable sections of California Code of Regulations Title 24, Part 1: 10-103.

> *"The standards shall be cost effective, when taken in their entirety, and when amortized over the economic life of the structure when compared with historical practice."*

Section 25402 also states that:

> *The commission shall periodically update the standards and adopt any revision which, in its judgment, it deems necessary. Six months after the commission certifies an energy conservation manual . . . , no city, county, city and county, or state agency shall issue a permit for any building unless the building satisfies the standards prescribed by the commission . . .*

Changes to the *Standards* occur periodically to account for improvements in conservation technologies, changes in the cost of fuels and energy-conserving strategies, and improved capabilities in analyzing building energy performance. In addition, modifications are also made to further improve compliance and enforcement.

1.3.2 Benefits of Energy Conservation

This section discusses some of the underlying reasons why *Standards* are important and necessary for California's energy future.

Energy Reliability and Demand

Buildings are one of the major contributors to electricity demand. With the 2000/2001 California energy crisis, the importance of conservation and efficiency is brought again to the forefront. The AB 970 changes will result in savings of over 800,000 therms/year of gas and about 100,000 MWh of electricity use. Perhaps more importantly, peak electricity demand is reduced by as much as 150 MW. Furthermore, these savings are cumulative, which means that they double in two years, triple in three, etc.

Comfort

Comfort is an important benefit of energy efficient houses. Energy efficient houses are well insulated, less drafty and use high performance windows and/or shading to reduce solar gains and heat loss. Poorly designed building envelopes result in houses that are less comfortable. Often comfort cannot be achieved in poorly designed houses, even with oversized heating and cooling systems.

Economics

For the homeowner, investing in building energy conservation helps to ensure that energy use in residences is affordable both now and into the future. Banks and other financial institutions recognize the impact of efficiency through energy efficient mortgages. From a larger perspective, the less California depends on depletable resources such as natural gas, coal and oil, the stronger and more stable the economy will remain in the face of energy cost increases. A Cost-effective investment in energy efficiency helps everyone.

Environment

In many parts of the world, the use of energy has led to oil spills, acid rain, smog and other forms of environmental pollution that have ruined the beauty people sought to enjoy. California is not immune to these problems, but the risks would be greater without appliance standards, building standards and utility programs that promote efficiency and conservation. Other benefits are reduced destruction of natural habitats, which in turn helps protect animals, plants and the natural systems.

Global Warming

Burning fossil fuel is a major contributor to global warming, as carbon dioxide is added to an atmosphere already containing 25% more than it did two centuries ago. Carbon dioxide and other gasses add an insulating layer to the earth that leads to global climate change. California Energy Commission (*Commission*) research shows that most of the sectors of the state economy face significant risk from climate change including water resources (from reduced snow pack), agriculture, forests and the natural habitats of a number of indigenous plants and animals.

Most scientists recommend that actions be taken to reduce emissions of carbon dioxide and other greenhouse gasses. While adding scrubbers to power plants and catalytic converters to cars is a step in the right direction, those actions do not limit the carbon dioxide we emit into the atmosphere. Using energy efficiently is a far-reaching strategy that can make an important contribution to the reduction of greenhouse gasses. The National Academy of Sciences urged the whole country to follow California's lead on such efforts, saying that we should make conservation and efficiency the chief element in energy policy. Their first efficiency recommendation was simple: Adopt nationwide energy efficient building codes. Energy conservation will not only increase comfort levels and save homeowners money; it will also play a vital role in creating and maintaining a healthy environment.

1.3.3 Which Standards Apply? Nonresidential vs. Residential

The California standards apply to both nonresidential and residential buildings. This *Manual* addresses the requirements for low-rise residential buildings. A companion manual addresses the requirements for nonresidential buildings, including hotels, motels, and residential buildings that are four stories or more in height.

Live-Work buildings are a special case, as they combine residential and nonresidential uses within individual units. Live-Work buildings are required to meet the applicable Low-rise or High-rise Residential Standards, due to the fact that these buildings operate (and therefore are conditioned) 24 hours per day. Lighting in designated workspaces is required to show compliance with the Nonresidential prescriptive lighting requirements (§146). Low-rise Residential Standards apply to live/work units that are part of a building with no more than three habitable stories. Note that the loft space in a unit with high ceilings is not counted as a separate story.

Table 1-4 – Building Types Covered by the Low-Rise Residential and Nonresidential Standards

Low-Rise Residential Standards	Nonresidential Standards
These standards cover all low-rise residential occupancies including single-family homes, duplexes, garden apartments and other housing types with less than three habitable stories.	These standards cover all nonresidential Uniform Building Code (UBC) occupancies (Group A, B, E, F, H, M or S), as well as high-rise residential (Groups R-1 and R-2 with four or more habitable stories), and all hotel and motel occupancies.
All single family dwellings of any number of stories (Group R-3) All duplex (two-dwelling) buildings of any number of stories (Group R-3) All multi-family buildings with three or fewer habitable stories (Groups R-1 and R-2) Additions and alterations to all of the above buildings	Offices Retail and wholesale stores Grocery stores Restaurants Assembly and conference areas Industrial work buildings Commercial or industrial storage Schools and churches Theaters Hotels and motels Apartment and multi-family buildings, and long-term care facilities (group R-2), with four or more habitable stories

The *Standards* define a habitable story as one that contains space in which humans may live or work in reasonable comfort, and that has at least 50% of its volume above grade.

The Uniform Building Code (UBC) defines a “guest room” as “any room or rooms used or intended to be used by a guest for sleeping purposes. Every 100 square feet of superficial floor area in a dormitory shall be considered to be a guest room”. Therefore, congregate residences, or any building with dormitory-style sleeping quarters, with six or more “guest rooms” is considered a hotel/motel for purposes of *Standards* compliance (§101(b)). Hotels/motels, regardless of the number of stories, comply with the requirements found in the Nonresidential Manual.

Example 1-1 – Historical Buildings

Question

When is an historical building exempt from the Energy Efficiency Standards (Title 24, Part 6)? Are additions to historical buildings also exempt?

Answer

A building is exempt from Part 6 when it is a “qualified historical building.” This term is defined in §8-302 of Title 24, Part 8 as a “structure or collection of structures, and their associated sites, deemed of importance to the history, architecture, or culture of an area by an appropriate local, state or federal governmental jurisdiction. This shall include designated structures on official existing or future national, state or local historical registers or official inventories, such as the National Register of Historic Places, State Historical Landmarks, State Points of Historical Interest, and officially adopted city or county registers or inventories of historical or architecturally significant sites, places or landmarks.”

“Additions which are structurally separated” from the historical building are not exempt from the Energy Efficiency Standards and must comply with current building codes (Historical Building Code, Title 24, Part 8, §8-504).

Example 1-2 – Mobile Homes

Question

Do the standards in Title 24, Part 6, apply to an addition to a mobile home?

Answer

No. Title 25 requirements, not Title 24, govern mobile homes, including additions to the unit. Jurisdiction in a mobile home park comes under the authority of Housing and Community Development. Jurisdiction of a mobile home on private property may come under the authority of the local building department.

The Administrative Regulations

References to Part 6 of Title 24 mean the Energy Efficiency Standards, also called the Energy Code. References to Part 1 of Title 24 mean the Administrative Regulations, of which §10-101 through §10-113 pertain to Part 6. The Administrative Regulations contain information about the documentation requirements, procedural information and other administrative requirements.

1.4 Introduction to the Residential Standards

This section introduces the basic concepts and approaches for complying with the low-rise residential standards.

1.4.1 Compliance Approaches

There are two methods for complying with the residential energy *Standards*:

- ***Prescriptive Packages*** *("Alternative Component Packages").* The simplest approach in which each individual component of the proposed building must meet a prescribed minimum energy requirement.
- ***Performance Methods*** *("Alternative Calculation Methods")*. Computer performance methods provide the most flexibility and accuracy in calculating energy use. Detailed accounting of energy *trade-offs* between measures is possible with the computer programs.

With either of these compliance paths, there are mandatory measures that still must be installed. Where superseded by a more stringent requirement to achieve compliance with the energy budget or prescriptive package, the more stringent feature becomes mandatory.

Note: The following buildings types are exempt from the prescriptive and performance standards.

(a) Seasonally occupied agricultural housing limited by state or federal agency contract to occupancy not more than 180 days in any calendar year.

(b) Low-rise residential buildings that use no energy obtained from a depletable source for either lighting or water heating and obtain heat from wood heating or other non-mechanical system.

1.4.2 Mandatory Measures

The mandatory measures require minimum ceiling, wall and raised floor insulation; minimum HVAC (heating, ventilating and air conditioning) and water heating equipment efficiencies, and other requirements. The mandatory measures are required features with either the prescriptive or performance standards. For example a building may only need R-7 floor insulation to meet the performance standards, but R-19 must be installed because that is the mandatory minimum.

1.4.3 Prescriptive Packages

The prescriptive approach is the least flexible yet simplest compliance path. It is simple because an applicant need only show that a building meets each minimum or maximum level prescribed in the set of requirements contained in a package; few calculations, if any, are needed to demonstrate compliance. However, both packages C and D require diagnostic testing of air distribution ducts, split system air conditioners and split system heat pumps.

Note: The Alternative to Package D allows use of higher performance fenestration, and sometimes, higher efficiency HVAC equipment in lieu of duct testing and installing TXVs.

Two prescriptive packages are designated for each climate zone by the letters C or D. Within any given package, every single feature must be met in order for the building to comply. Package D requirements form the basis of trade-offs using the performance method. There is also an Alternative to Package D that substitutes high efficiency equipment and high performance glazing (depending on climate zone) instead of duct sealing, TXVs or refrigerant charge and airflow measurement.

Package C has higher insulation levels, but permits electric resistance heat. Package C may only be used in areas where natural gas is not available."

The following compliance documentation showing that the building complies is required to be submitted with the prescriptive approach.

CF-1R	Certificate of Compliance (required)
MF-1R	Mandatory Measures Checklist (required)
Form 3R	Construction Assembly U-factor (if applicable)
Form 3RM	Masonry Wall Assembly (if applicable)
Form CF-4R	Field Verification and Diagnostic Testing (if applicable). This form is usually required when Package D or Package C is used since the package requires diagnostic testing of air distribution ducts, split system air conditioners and heat pumps.
Form S	Solar Heat Gain Coefficient Worksheet (if applicable)
DHW-1	Water Heating Calculations (if applicable)

Two additional forms, the Installation Certificate (CF-6R) and the Insulation Certificate (IC-1) are required during construction and must be posted or made available to the enforcement agency during building inspection. Refer to Chapter 3 for a complete discussion of prescriptive compliance. Refer to Chapter 7 for details on how the prescriptive approach is used with additions.

1.4.4 Performance Methods

The use of Energy Commission-approved *computer method*s represents the most detailed and sophisticated method of compliance. While this approach requires the most effort, it also provides the greatest flexibility. The computer program automatically calculates the *energy budget* for space conditioning. The budget is determined from the *standard design*, a version of the building, which is upgraded or downgraded to achieve minimum compliance with the prescriptive Package D conservation features.

The energy budget for space conditioning is expressed in thousands of Btu (kBtu) per square foot per year. The program also calculates the budget for water heating energy use in kBtu per dwelling unit (see Chapter 6). The water-heating budget is translated into a kBtu per square foot per year value and added to the space-conditioning budget to yield the combined energy budget. To comply with the *Standards*, the predicted combined "Energy Use" of the Proposed Design cannot exceed the combined "Energy Budget" of the Standard Design.

The following compliance documentation showing that the building complies is required to be submitted with the performance approach.

- CF-1R, Certificate of Compliance (required)
- MF-1R, Mandatory Measures Checklist (required)
- CF-2R, Computer Method Summary (required)
- Form 3R, Construction Assembly U-factor (if applicable)

The Installation Certificate (CF-6R) and Insulation Certificate (IC-1) are required during construction. Refer to Chapter 5 for a detailed explanation of compliance using approved computer methods. If features are used for compliance that require field verification and diagnostic testing a CF-4R, as detailed in Chapter 4, is required at the completion of construction.

1.4.5 California Climate Zones

Energy use depends in part on climate conditions, which differ throughout the state. To standardize calculations and to provide a basis for presenting the criteria, the Energy Commission has established 16 climate zones, which are used with both the low-rise residential and the nonresidential standards. See the figure below.

Appendix D has a list of California cities showing the climate zone for each. More detailed climate zone boundary descriptions are available in the Energy Commission publication *California Climate Zone Descriptions for New Buildings, July 1995*, (P400-95-041).

Note: Cities may occasionally straddle two climate zones. In these instances, the exact building location and correct climate zone should be verified before any calculations are performed. If a single building development is split by a climate zone boundary line, it must be designed to the requirements of the climate zone in which 50% or more of the dwelling units are contained (see also Chapter 8).

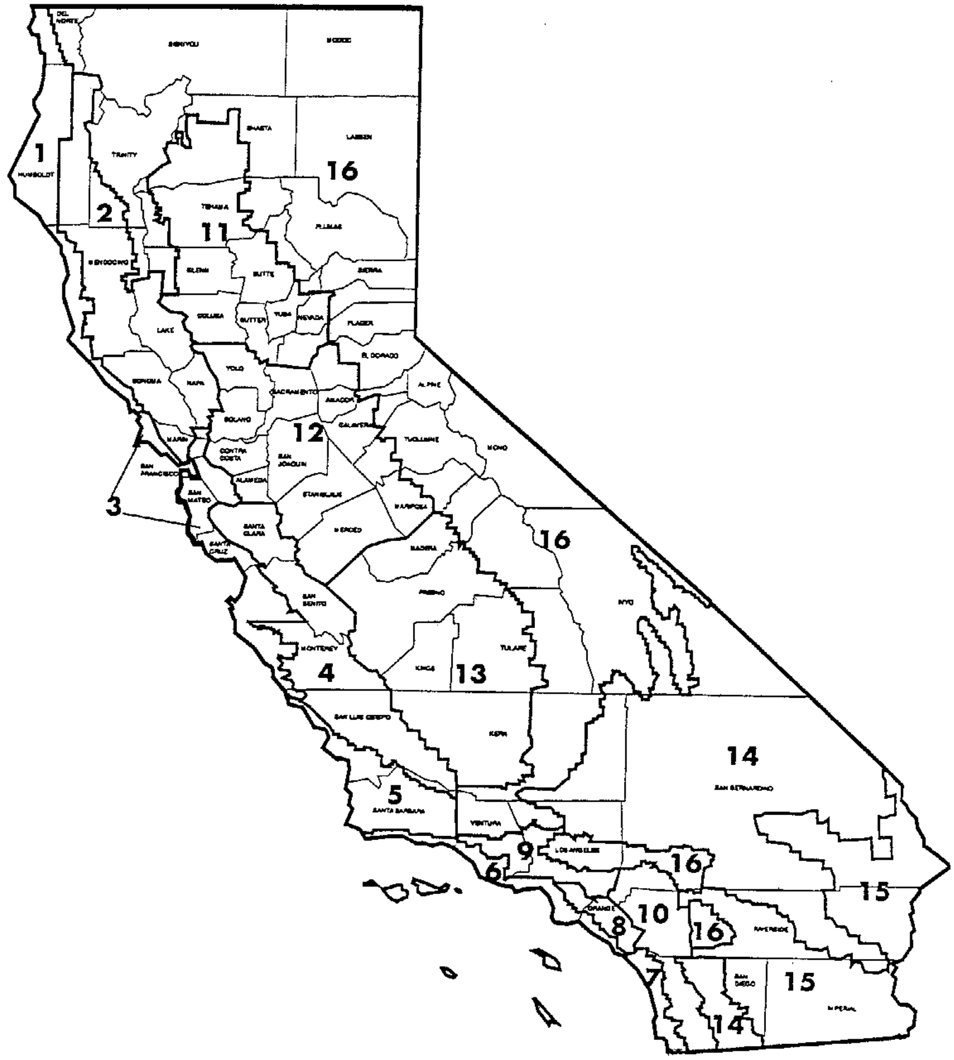


Figure 1-1– California Climate Zones

1.4.6 Compliance and Enforcement Phases of the Building Process

The goals set by any building standard are no better than the level of cooperation and communication among the parties involved in the building process. These parties may include some or all of the following: architect or designer, builder/developer, purchasing agent, general contractor, subcontractor/installer, energy consultant, plan checker, inspector, realtor and owner/first occupant. To help resolve potential energy compliance issues, the *Standards* specify detailed reporting requirements that are intended to provide design, construction, and enforcement parties with needed information to complete the building process and insure the energy features are installed. The above parties are accountable for ensuring that the building's energy features are installed in their phase of responsibility.

Design

This phase generally sets the stage for the type and style of building to be constructed. In addition to issues concerning zoning, lot orientation and infrastructure layout, the building's overall design and energy features are conveyed to working drawings of the building for construction. Parties associated with this phase must insure the energy features meet compliance with the *Standards* and that these features are detailed on the construction plans.

Plan Check — Local building departments check plans for conformance to building standards. This includes health and safety requirements, such as fire and structural, along with energy requirements. Vague and/or missing details on the construction plans must be changed or clarified by parties involved in the design phase of the building process.

Construction — Upon receiving a building permit from the local building department, parties associated with this phase construct the building according to the approved construction plans. It is not unusual for changes to be made "in the field". Field changes that may result in non-compliance require building department approval of revised plans and energy compliance documentation demonstrating that the building is still in compliance.

Site Inspection — Local building departments, or their representatives, inspect all new buildings to insure conformance to building standards. Field construction changes and non-complying energy features require parties associated with previous phases to repeat and revise their original efforts.

Occupancy — The *Standards* require that the building owner at occupancy receive information indicated on forms:

- Certificate of Compliance (CF-1R)
- Mandatory Measures Checklist (MF-1R)
- Installation Certificate (CF-6R)
- Insulation Certificate (IC-1)

They must also receive either:

- A manual which contains instructions for operating and maintaining the features of their building efficiently, or
- *The Guide to California Home Comfort and Energy Savings* (P400-99-031).

For individually owned units in a multi-family building the documentation is provided to the owner of the dwelling unit or to the individual(s) responsible for operating the feature, equipment or device. The maintenance information is provided to whomever is responsible for maintaining the feature, equipment or device. Information must be for the appropriate dwelling unit or building (photocopies are acceptable).

1.4.7 How to Comply with the Standards

§10-103(a)(2)

B. Plans and specifications submitted with each application for a building permit shall show the characteristics of each feature, material, component, and manufactured device proposed to be installed in order to have the building meet the requirements of Part 6, and of any other feature, material, component, or manufactured device that Part 6 requires be indicated on the plans and specifications. If any characteristic is materially changed before final construction and installation, such that the building may no longer comply with Part 6, the building must be brought back into compliance, and so indicated on amended plans, specifications, and Certificate(s) of Compliance and shall be submitted to the enforcement agency. Such characteristics shall include the efficiency (or other characteristic regulated by Part 6) of each device.

C. All documentation necessary to demonstrate compliance for the building, and of the sections of Part 6 with which the building is intended to comply shall be submitted with each application for a building permit. The forms used to demonstrate compliance shall be readily legible and of substantially similar format and informational order and content to the appropriate forms in the Residential or Nonresidential Manual, as defined in Part 6.

Title 24, Part 6 contains the Energy Efficiency Standards. Part 1 contains administrative, documentation, and procedural requirements for complying with the *Standards*.

To comply with the Residential Standards, the permit applicant follows these general steps:

- Verify that the Low-rise Residential Standards apply and that the correct climate zone is used for the building location.
- Demonstrate that the building meets the *Standards* with one of the two compliance options: prescriptive packages or approved performance method.
- Include all appropriate mandatory features and provisions applicable to the building design.
- Document and coordinate all calculations, plans and specifications. This includes completing a *Certificate of Compliance (CF-1R)* that must appear on the drawings. See below for additional information on the CF-1R.
- Install all specified measures in the building. The person responsible for construction or the installer of equipment must either post the installation certificate (Form CF-6R) or keep it with the plans and make it available to the inspector. This form, or several forms that together contain all the required information, must identify and provide the relevant energy efficiency data for each HVAC system, water heater system, fenestration product, faucet and showerhead, and any other manufactured device regulated by the *Standards*.

  In addition, an Insulation Certificate (IC-1) must also either be posted by the insulation installer in a conspicuous location or kept with the plans and made available to the inspector.
- For new dwelling units, deliver a copy of *The Guide to California Home Comfort and Energy Savings* or an equivalent document to the building owner at the time of occupancy along with copies of the CF-1R, MF-1R, CF-6R and IC-1. See below for additional information about *The Guide to California Home Comfort and Energy Savings* (formerly the Home Energy Manual).

The enforcement agency may require the person with overall responsibility for the construction to provide any other reasonable information to determine that the building, as constructed, is consistent with approved plans and specifications.

Example 1-3 – Form CF-6R

Question

What is a CF-6R and why is it required?

Answer

The CF-6R is an installation certificate for manufactured devices regulated by the appliance standards (see Part 6 of Title 24, §111) and a certification of installer tests for duct efficiency and reduced envelope leakage credits. The certification must include a statement indicating that installed devices conform to appliance and building standards and to any additional requirements contained in the plans and specifications. The certificate must be signed by the person with overall responsibility for construction or the person(s) responsible for installing the certified devices and/or appliances. This certificate must either be posted adjacent to the building permit or made available to the inspector during construction.

Information required on the CF-6R such as manufacturer, model number and efficiency helps to ensure that installed devices conform to specifications on the CF-1R and meet or exceed minimum efficiency requirements. It also serves to advise the homeowner what devices were installed in their home.

1.4.8 Compliance Documentation

Certificate of Compliance (CF-1R)

§10-103(a)(2)

A. For all new buildings designated to allow a conditioned use of an occupancy group or type regulated by Part 6 the applicant shall file the appropriate Certificate(s) of Compliance on the plans. The Certificate(s) shall indicate the features and performance specifications needed to comply with Part 6, and shall be approved by the local enforcement agency by stamp or authorized signature. The Certificate(s) of Compliance and supporting documentation shall be readily legible and of substantially similar format and informational order and content to the appropriate Certificate(s) of Compliance and supporting documentation in the appropriate Residential or Nonresidential Manual, as defined in Part 6.

All building permit applicants shall file a certificate of compliance on the plans as required by Title 24, Part 1, §10-103(a) 2 A of the Code of Regulations.

The items listed in the CF-1R form represent a set of minimum energy performance specifications, including the results of the heating load calculation. While a performance method analysis may be used to show compliance on a particular combination of conservation measures, the building must be constructed to meet or exceed the performance level established by all of the features and specifications contained in the CF-1R.

Placing a transparency of the CF-1R on the drawings, taping a CF-1R to the drawings or printing the CF-1R information directly on the drawings may meet the requirement that the certificate be on the plans. Verify with the local enforcement agency, which is acceptable.

A blank copy of the recommended CF-1R form is contained in Appendix A. The same information is submitted regardless of the compliance approach. A completed example of the CF-1R form is in Chapter 5.

Responsibility for Signing the CF-1R

§10-103(a)(1)

The Certificate(s) of Compliance described in §10-103 shall be signed by the person(s) responsible for the building design to certify conformance with Part 6. The signer(s) shall be eligible under Division 3 of the Business and Professions Code to sign such documents. If more than one person has responsibility for building design, each person may sign the document or documents applicable to that portion of the design for which the person is responsible. Alternatively, the person with chief responsibility for design may prepare and sign the document for the entire design.

Subject to the preceding paragraph, persons who prepare energy compliance documentation shall sign a statement that the documentation is accurate and complete.

The signature on the Certificate of Compliance of the "Designer" is the person who takes responsibility for the building design being in compliance with the *Standards*. This person must have the authority given by the *Business and Professions Code* for the type of construction.

Note: The documentation author is not subject to the limitations and restrictions of the *Business and Professions Code*. The documentation author's signature is to verify that the documentation is accurate and complete.

Business and Professions Code

If the building type requires that a licensed individual take responsibility for design under the *Business and Professions Code*, then that individual must sign as the designer and lists his or her license number above the signature. When the building type does not require the signature of a licensed individual, another individual may take responsibility as designer.

The person who signs as the designer certifies that he or she has either:

- Directly prepared and coordinated the compliance documents; *or*
- Delegated responsibility to an energy documentation author who has provided the compliance analysis and documentation under their direction.

The documentation author also signs the CF-1R to indicate their responsibility for the accuracy and completeness of the compliance documentation.

Section 5537(a) and 6737.1 of the *Business and Professions Code* specifically exclude the following building types from requiring a licensed architect and engineer to design the building:

> *"5537 [and 6737.1]. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*
>
> *"(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.*
>
> *"(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot."*
>
> *"(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height."*
>
> *"(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved."*
>
> *"(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985."*

Mandatory Measures Checklist: Residential (MF-1R)

The Mandatory Measures Checklist for Residential Buildings is provided as a convenient summary of the mandatory measures required for low-rise residential buildings.

The items listed on the MF-1R form represent minimum component performance specifications that must be installed at or above the efficiency levels specified. In some cases, a specific compliance approach has requirements that supercede and go beyond the mandatory measure requirements. For example, Package D requires R-30 ceiling insulation that is more than the mandatory measure minimum of R-19. While the performance approach allows the *Standards* to be met with more flexibility, the mandatory measures must always be met or exceeded regardless of the compliance approach.

Field Verification and Diagnostic Testing Certificate (CF-4R)

When compliance documentation requires field verification and/or diagnostic testing of specific energy efficiency improvements as a condition for those improvements to qualify for Title 24 compliance credit, an approved HERS provider and certified rater must be used to conduct the field verification and diagnostic testing.

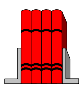
The HERS rater providing the diagnostic testing and verification shall sign and date a *Certificate of Field Verification and Diagnostic Testing* (CF-4R) certifying that they have verified that the requirements for compliance credit have been met. The HERS rater shall provide this certificate to the builder and the HERS provider. Raters shall provide a separate *Certificate of Field Verification and Diagnostic Testing* for each house the rater determines has met the diagnostic requirements for compliance. The HERS rater shall not sign a *Certificate of Field Verification and Diagnostic Testing* for a house that does not have a CF-6R signed by the installer.

Installation and Insulation Certificates (CF-6R and IC-1)

The *Standards* require that the CF-6R be signed by the installer of each device (heating, cooling, water heating/plumbing equipment, heating and cooling distribution systems, air infiltration reduction systems, and fenestration products) or alternatively, the person with chief responsibility for construction.

The insulation installer must sign the IC-1.

Persons signing these forms are verifying that the installed efficiencies meet or exceed those used for compliance with the *Standards* as shown on the CF-1R.



§10-103(a) (3) and (4)

(3) Installation Certificate.

(A) The person with overall responsibility for construction or the person or persons responsible for the installation of regulated manufactured devices shall post, or make available with the building permit(s) issued for the building, the installation certificate(s) for manufactured devices regulated by the appliance standards or Part 6. Such installation certificate(s) shall be made available to the enforcement agency for all appropriate inspections.

These certificates shall:

1. *Identify features required to verify compliance with the appliance standards and Part 6.*
2. *Include a statement indicating that the installed devices conform to the appliance standards and Part 6 and the requirements for such devices given in the plans and specifications approved by the local enforcement agency.*
3. *State the number of the building permit under which the construction or installation was performed.*
4. *Be signed by the individual eligible under Division 3 of the Business and Professions Code to accept responsibility for construction, or their authorized representative. If more than one person has responsibility for building construction, each person may prepare and sign the part of the document applicable to the portion of construction for which they are responsible; alternatively, the person with chief responsibility for construction may prepare and sign the document for the entire construction).*

(B) The enforcement agency may require the person with overall responsibility for the construction to provide any other reasonable information to determine that the building as constructed is consistent with approved plans and specifications and complies with Part 6.

(C) If construction on any portion of the building subject to Part 6 will be impossible to inspect because of subsequent construction, the enforcement agency may require the installation certificate(s) to be posted upon completion of that portion.

(4) Insulation Certificate.

After installing wall, ceiling, or floor insulation, the installer shall make available to the enforcement agency or post in a conspicuous location in the building a certificate signed by the installer stating that the installation is consistent with the plans and specifications described in Section 10-103(a)2.A and for which the building permit was issued and conforms with the requirements of Part 6. The certificate shall also state the manufacturer's name and material identification, the installed R-value, and (in applications of loose fill insulation) the minimum installed weight per square foot consistent with the manufacturer's labeled installed design density for the desired R-value.

The IC-1 must be posted at the job site in a conspicuous location (e.g., in the garage) or kept with the building permit and made available to the enforcement agency. The IC-1 must document the actual value of the installed insulation. Both forms must be provided to the building owner at occupancy.

The Installation Certificate (CF-6R) and Insulation Certificate (IC-1) are required to be posted at the job site or made available with the building permit during the construction phase of the project. The CF-6R is used to document all equipment and fenestration products installed in the building and installer test results for duct efficiency and reduced infiltration measures. The installer is responsible for verifying and complying with the efficiencies used to achieve compliance, as indicated on the CF-1R. These efficiencies (such as AFUE or HSPF for heating equipment, SEER for cooling equipment, energy factor for water heating, and U-factor for fenestration products) must meet or exceed each value shown on the CF-1R. This means that the AFUE, HSPF, SEER or EF must be greater than or equal to the CF-1R value and the U-factor and SHGC must be equal to or less than the CF-1R value.

Note: In a cold climate where heating loads significantly dominate cooling loads, a lower SHGC may be worse for the overall energy efficient operation of the home.

Example 1-4 – Plan Checking/ Field Inspection Requirements

Question

What are the plan checking/field inspection requirements related to the CF-6R?

Answer

The CF-6R (Installation Certificate) is not required to be submitted with other compliance documentation at the time of permit application, but rather is posted or made available for field inspection. A field inspector will want to check the equipment installed against what is listed on the CF-6R and compare the CF-6R and CF-1R for consistent equipment characteristics.

For a performance approach that relies on duct efficiency improvements or reduced envelope leakage, the field inspector should check the Special Features and Modeling Assumptions and HERS Required Verification listings on the CF-1R for required installer tests for reduced duct leakage or building pressurization and verify that these tests were performed and documented on the Installation Certificate CF-6R.

California Code of Regulations §10-103(a)(3)(B) allows the enforcement agency to request additional information to determine that the building is constructed consistent with approved plans and specifications. When equipment efficiencies above the minimum requirements are shown on the CF-1R (e.g., 12 SEER cooling equipment; 0.63 energy factor water heater), the building department should have procedures in place to verify efficiency. Requiring proof of efficiency from the installer, such as a copy of the appropriate page from a directory of certified equipment, is one possibility. Another possibility is to require that the applicant send a duplicate of the CF-6R through plan check for verification.

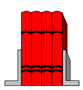
Question

What happens to the CF-6R after the final inspection?

Answer

California Code of Regulations §10-103(b) requires that the builder provide to the "building owner, manager, and the original occupants the appropriate Certificate(s) of Compliance and a list of the features, materials, components, and mechanical devices installed in the building, and instructions on how to use them efficiently" (italics added). At a minimum, information on the CF-6R and CF-1R must be provided to the original building occupants as well as operating and maintenance information such as the "The Guide to California Home Comfort and Energy Savings" (CEC publication number P400-99-003-FXX, where the XX are numbers that relate to a series of subject matter inserts that can be placed in the guide).

1.4.9 The Guide to California Home Comfort and Energy Savings



§10-103(b)

Operating and Maintenance Information to be Provided by Builder.

(1) Operating Information. The builder shall provide the building owner at occupancy the appropriate Certificate(s) of Compliance and a list of the features, materials, components, and mechanical devices installed in the building and instructions on how to operate them efficiently. The instructions shall be consistent with specifications set forth by the Executive Director.

For residential buildings, such information shall, at a minimum, include information indicated on forms Certificate of Compliance (CF-1R), Mandatory Measures (MF-1R), Installation Certificate (CF-6R), Insulation Certificate (IC-1), and a manual which provides all information specified in this Section 10-103(b). The Home Energy Manual (P400-92-031) may be used to meet the requirement for providing this manual.

For dwelling units, buildings or tenant spaces which are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for operating the feature, material, component or mechanical device installed in the building.

(2) Maintenance Information. The builder shall provide to the building owner at occupancy maintenance information for all features, materials, components, and manufactured devices that require routine maintenance for efficient operation. Required routine maintenance actions shall be clearly stated and incorporated on a readily accessible label. The label may be limited to identifying, by title and/or publication number, the operation and maintenance manual for that particular model and type of feature, material, component, or manufactured device.

For dwelling units, buildings or tenant spaces which are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for maintaining the feature, material, component, or mechanical device installed in the building.

The Energy Commission has prepared *The Guide to California Home Comfort and Energy Savings* (P400-99-003) as a replacement for the *Home Energy Manual*. Copies of the *Guide* can be obtained by contacting the *Energy Standards Hotline* at (800) 772-3300. The guide provides information to the homeowner regarding energy saving features and energy efficient operation and maintenance of their home. This is an example of the type of guide or manual that must be provided to fulfill the requirements of the standards. The Energy Commission's *The Guide to California Home Comfort and Energy Savings* may be used to meet these requirements or can be used as a sample for builders to develop their own guide that meets the requirements.

The owner of the residence when it is first occupied must receive *The Guide to California Home Comfort and Energy Savings* or, at the builder's option, a manual which otherwise provides all information specified in §10-103(b). Copies of the CF-1R, MF-1R, CF-6R, and IC-1 compliance forms must be included with either the *Guide* or the builder's manual.

In multi-family buildings or where central systems provide space conditioning or water heating, the information is provided to whoever is responsible for operating and maintaining the building or equipment.

Example 1-5 – Administrative Regulations

Question

As a general contractor, when I have finished building a residence, is there a list of materials I am supposed to give to the building owner?

Answer

The "owner at occupancy" must receive a copy of the following completed forms for that dwelling unit:

- Certificate of Compliance (CF-1R)
- Mandatory Measures Checklist (MF-1R)
- Installation Certificate (CF-6R)
- Insulation Certificate (IC-1)

In addition, they must receive either:

- A manual which contains instructions for operating and maintaining the features of their building efficiently, or
- *The Guide to California Home Comfort and Energy Savings* published by the Energy Commission.

Question

I built some multi-family buildings and have some questions about the information I must provide (as required by Administrative Regulations, §10-103). Specifically:

If the building is a condominium, can I photocopy the same information for all units?

When the building is an apartment complex (not individually owned units), who gets the documentation?

If an apartment is converted to condominiums, does each owner/ occupant receive copies of the documentation?

Answer

Photocopied information is acceptable. It must be obvious that the documentation applies to that dwelling unit—that is, the features installed must match the features shown on the Installation Certificate. If compliance documentation is for a "building," a photocopy of the compliance forms for that building must be provided. If individual compliance is shown for each unique dwelling unit, a photocopy of the documentation, which applies to that dwelling unit, must be provided.

The documentation and operating information is provided to whomever is responsible for operating the feature, equipment or device (typically the occupant). Maintenance information is provided to whomever is responsible for maintaining the feature, equipment or device. This is either the owner or a building manager. (§10-103(b) (1)-(2).)

If, during construction, the building changes from an apartment to condominiums, each owner at occupancy would receive the documentation. If an existing apartment building changes to condominiums at a later date, the documentation requirements are triggered only by a building permit application requiring compliance with the Energy Efficiency Standards. (Changing occupancy does not trigger compliance with the *Standards*.)

Question

What is my responsibility with respect to the CF-6R (Installation Certificate) (a) as an inspector and (b) as a builder?

Answer

The building inspector is responsible for checking the CF-6R at appropriate inspections to be sure it is filled out and signed for the completed work. Inspectors can verify that the installed features are "consistent with approved plans," as indicated on the Certificate of Compliance (CF-1R) form. Since the CF-6R may be posted at the job site or kept with the building permit, the inspector can request that this form be made available for each appropriate inspection. It is not advisable to wait until the final inspection to check the CF-6R (§10-103(d)(2)).

The general contractor, or his/her agent (such as the installing contractor), takes responsibility for completing and signing the form for the work performed. (A homeowner acting as the general contractor for a project may sign the CF-6R.) The compliance statement for their signature indicates that the equipment or feature: is what was installed; is equivalent or more efficient than required by the approved plans (as indicated on the CF-1R); and meets any certification or performance requirements (§10-103(a)(3)(A)).

1.5 Code Decisions: Case Studies

The first step in any project is to establish which standards apply and which compliance requirements must be met. Once that is done, compliance options can be considered and appropriate documentation prepared (or, in the case of enforcement, forms reviewed and data verified).

Be sure that basic code decisions are correct; otherwise a considerable waste of effort may be expended attempting to meet the standards using an incorrect compliance approach. If in doubt, verify fundamental assumptions about the applicability of the standards for a specific project with the local enforcement agency before performing calculations to demonstrate compliance. The Energy Commission Energy Hotline is also available for assistance as explained in Section 1.6.

The following examples present several residential building scenarios and explain each in the context of which standards, if any, apply.

Example 1-6 – Code Decisions Scenarios

Question

A sunspace addition is designed with no mechanical heating or cooling and a glass sliding door separating it from all existing conditioned space. Under what conditions will the *Standards* not apply to this addition?

Answer

The *Standards* do not apply if the space is unconditioned (see Appendix G *Glossary*). This is the case if:

- The new space is not provided with heating or cooling (or supply ducts);
- The new space can be closed off from the existing house with weather-stripped doors; and,
- The addition is not indirectly conditioned space (see Appendix G Glossary).

Question

Three stories of residential dwelling units are planned over a first story that includes retail and restaurant occupancies. Should the residential apartments comply with the Residential Standards?

Answer

No. The residential apartments must comply with the Nonresidential (High-rise Residential) Standards since the structure contains four habitable stories and, as a whole structure, is a high-rise building. See Mixed Occupancy Buildings in Section 8.2 to determine whether all four stories can be treated as the dominant occupancy.

Question

A four-story single-family townhouse has been constructed. Should the townhouse comply with the Residential Standards?

Answer

Yes. As a group R-3 occupancy, the Residential Standards apply. The building is not an apartment house (which, according to the UBC, must be at least three dwelling units).

Question

A 1200 ft^2 manager's residence is being constructed as part of a new conditioned warehouse building with 14,000 ft^2. Which standards apply?

Answer

The whole building can comply with the Nonresidential Standards, and the residential unit is not required to comply separately since it is a subordinate occupancy containing less than 10% of the total conditioned floor area (see Section 8.2). However, the residential dwelling unit must meet all low-rise residential mandatory measures (see Chapter 2).

Question

Assume the same scenario as in the previous example, except that the dwelling unit is new and the remainder of the building is existing. Do the Residential Standards apply?

Answer

Yes. Since 100% of the addition being permitted is a low-rise residential occupancy, compliance under the Residential Standards is required (see Chapter 7).

Question

An existing duplex is remodeled without increasing the amount of conditioned space. Do the Residential Standards apply?

Answer

Even though no new conditioned space is being created, the remodel must comply with applicable mandatory measures of the Residential Standards. See Section 7.5.

Question

An existing house is remodeled without increasing conditioned space. New windows are replacing old ones, and a new window is being added. Several exterior walls are being opened up in order to install new wiring. What requirements will apply?

Answer

The new window that is being added must have a maximum U-factor of 0.75 and must meet the SHGC requirements of Package D. The other windows that are being replaced do not have to meet U-factor or SHGC requirements. The house must also comply with the mandatory measures applicable to the windows and wall insulation described in Chapter 2.

Question

A 95 ft^2 family room is being added to an existing 2800 ft^2 house. What are the applicable compliance requirements?

Answer

The addition alone must comply with the Residential Standards or the existing-plus-addition must comply as explained in Section 7.1. If the prescriptive compliance approach is used for the addition alone, special prescriptive requirements apply (see Chapter 7, Table 7-1).

Question

A residence is being moved to a different location. What are the applicable compliance requirements?

Answer

Since this is an existing conditioned space, the requirements applicable to alterations would apply to any alterations being made (Chapter 7). The building does not need to show compliance with the current energy standards applicable to new buildings or additions.

Question

A previously conditioned retail space is remodeled to become a residential dwelling. What are the applicable compliance requirements?

Answer

The residential dwelling is treated as if it were previously a residential occupancy. In this case, the rules that apply to residential alterations (Chapter 7) are applied.

Question

A 10,000 ft^2, 16-unit motel is constructed with an attached 950 ft^2 manager's residence. What are the applicable compliance requirements?

Answer

The manager's unit is less than 10% of the total floor area, so compliance of the whole building as the predominant motel occupancy would satisfy the requirements of the standards (see Section 8.2). Either the entire building must comply with the Nonresidential (High-Rise Residential and Hotel/Motel) Standards; or the manager's residence must comply with the low-rise Residential Standards and the motel occupancy portion of the building must comply with the Nonresidential Standards.

Question

A subdivision of detached homes includes several unit types, each of which may be constructed in any orientation. What are the applicable compliance requirements?

Answer

The low-rise Residential Standards are applied to each building type. All four cardinal orientations may be shown to comply or each individual unit in its planned orientation must comply (see Section 8.3).

Question

A four-story apartment building has three stories of apartments and a garage on the first floor. What are the applicable compliance requirements?

Answer

For standards compliance, the Low-rise Residential Standards apply since the building has fewer than four habitable stories.

Note: The UBC considers this a four-story building. As a high-rise building for compliance with other building codes, different health and safety regulations apply.

1.6 Where To Get Help

If the information contained in the standards or this *Manual* is not sufficient to answer a specific question concerning compliance or enforcement, technical assistance is available from the Energy Commission's Energy Hotline, weekdays from 8 a.m. - noon and 1 p.m. - 4 p.m.:

(800) 772-3300
(916) 654-5106

1.6.1 Publications

Publications may be ordered from:

Publications Unit
California Energy Commission
1516 Ninth Street, MS-13
Sacramento, CA 95814
(916) 654-5200 (no phone orders)

Appendix E contains a list of available publications.

The CEC publishes the *Blueprint*, a quarterly newsletter that answers questions related to enforcement and compliance that are not covered in the standards, provides updated information on technical assistance and computer compliance programs, and lists training opportunities offered throughout the state. The *Blueprint* is available at the CEC website at http://www.energy.ca.gov/title24.

Forms and pages of publications can be faxed by an automated system at any time. This system is available by calling (916) 653-6830. You must enter a document number (a list of documents and document numbers is available on the system) and your fax number.

1.6.2 Appliance Certification Information

Any directory that has been approved by the Commission can be used for determining if appliances meet the standards. The Energy Hotline (see above) can verify certification of appliances and provide information on appropriate directories.

The *Commission's* web site now includes references to listings of the most energy efficient appliances for several appliance types. The web site address is: http://www.energy.ca.gov/efficiency/appliances/index.html.

The complete appliance databases can be downloaded from the *Commission's* internet web site at http://www.energy.ca.gov/appliances/appliance/. This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress these files. The user must then download a description file that provides details on what is contained in each of the data fields. With the help of these files and database software, the data can be sorted and manipulated.

1.6.3 Insulation Certification

Manufacturers whose insulating materials are certified for sale in California are listed in the Department of Consumer Affair's *Consumer Guide and Directory of Certified Insulation Material*. Each building department receives a copy of this directory. If an insulating product is not listed in the directory, or to purchase a directory, contact the Department of Consumer Affairs, Thermal Insulation Program, at (916) 574-2065.

1.6.4 Training Opportunities

If you are interested in attending a training seminar on the Residential Standards:

- Sign up to receive a free subscription to the *Blueprint*, a quarterly newsletter that answers questions on the standards not covered elsewhere, updated information on technical assistance and computer compliance programs, and lists training opportunities offered throughout the state. An order form is provided at the front of this *Manual*. Blueprints can also be downloaded in electronic form from www.energy.ca.gov/title24.
- Some colleges provide classes on building energy conservation and the energy standards. Information about these classes should be obtained directly from the college.
- Energy consulting firms, organizations of energy consultants, building industry and trade associations, and organizations that serve building officials will often sponsor or conduct classes on compliance and enforcement of the Title 24 building energy efficiency standards. These classes are often listed in the *Blueprint* or posted on the Commission's website at http://www.energy.ca.gov/title24.

2 Mandatory Measures

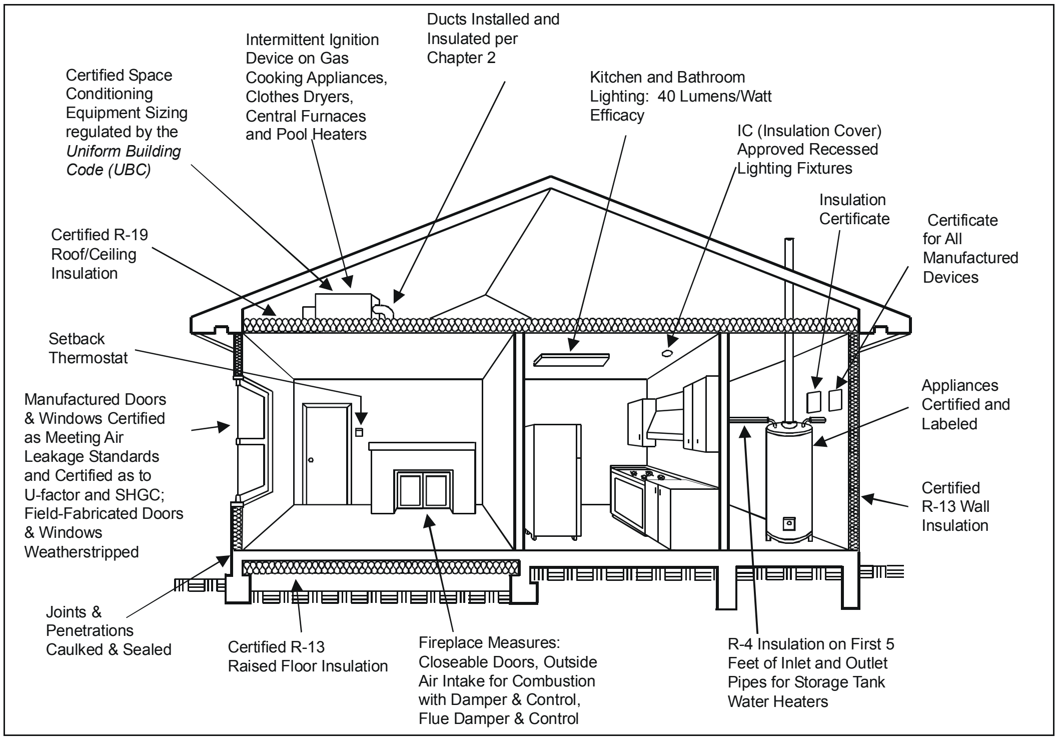
This chapter discusses the conservation features and devices mandated by the *Energy Efficiency Standards* (standards). These requirements apply with either the prescriptive or performance approaches to compliance. This chapter covers the following topics.

- Introduction
- Insulation
- Fenestration / Exterior Doors
- Infiltration and Moisture Control
- Space Conditioning
- Water Heating and Plumbing
- Lighting
- Compliance Documentation

2.1 Introduction

All new residential construction covered by the standards and explained in this *Manual* must meet or exceed certain minimum energy efficiency requirements, regardless of the compliance approach. These minimum requirements are referred to in the standards as ***mandatory measures.*** The mandatory measures address all aspects of energy efficient design and construction. The requirements are summarized in Figure 2-1. More detail is provided in the sections that follow.

Figure 2-1 – Summary of Mandatory Measures



The mandatory measures represent a minimum level of efficiency. To achieve compliance with other parts of the standards, higher levels of efficiency may be required.

2.2 Insulation

The R-value of insulation (or any material or building component) is the measure of its thermal resistance expressed in ft^2-hr-°F/Btu. This value may be obtained from Appendix B or from manufacturer's literature.

The rated R-value of mineral fiber (batt) insulation is based upon its fully expanded thickness. When the insulation is compressed, the R-value is reduced. The most common insulation compression occurs with R-19 and R-22 insulation batts installed in locations with a nominal 6 inch framing that is actually only 5.5 inches thick. To achieve its rated insulation value, an R-19 batt of insulation expands to a thickness of six and one quarter inches. If it is compressed into 2x6 framing with an actual depth of 5.5 inches, the insulation R-Value is lowered to R-17.8. See Table 2-1 for some common installed insulation values.

Table 2-1 – Installed R-Values for Mineral Fiber Batt Insulation[1]

Standard R-Value	Nominal Lumber Size	Actual Cavity Depth	Installed R-Value
13 (3.625")	2x4	3.5"	13
15 (3.5”)	2x4	3.5	15
19 (6.25")	2x6	5.5"	17.8
21 (5.5”)	2x6	5.5	21
22 (6.75")	2x6	5.5"	20
30 (9.5")[2]	2x10	9.25"	30
38 (12")[2]	2x12	11.25"	37

1. Based on manufacturer's data.
2. Note that batt insulation with these R-values is available in smaller thicknesses. R-30 may be achieved with an 8.25-inch to 8.5-inch batt, and R-38 may be achieved with a 10.25-inch to 10.5-inch batt. If this thinner insulation is used in the framing sizes listed here, the insulation would retain its full rated R-value because it would not be compressed.

The R-value of loose fill insulation depends on proper installation. See Section 2.2.3.

2.2.1 Certification of Insulating Material

Requirements

Insulating materials must be certified and labeled by the manufacturer. Urea formaldehyde foam insulation may only be installed in exterior walls with an interior vapor barrier. Insulating materials installed in exposed applications must have a flame spread of 25 or less and a smoke development rating of 450 or less.

§118

(a) Certification by Manufacturers. Any insulation of the type and form listed below may be installed only if the manufacturer has certified that the insulation complies with the California Code of Regulations, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.

Type	*Form*
Aluminum foil	*reflective foil*
Cellular glass	*board form*
Cellulose fiber	*loose fill and spray applied*
Mineral aggregate	*board form*
Mineral fiber	*blankets, board form, loose fill*
Perlite	*loose fill*
Phenolic	*board form*
Polystyrene	*board form, molded extruded*
Polyurethane	*board form and field applied*
Polyisocyanurate	*board form and field applied*
Urea formaldehyde	*foam field applied*
Vermiculite	*loose fill*

(b) Installation of Urea Formaldehyde Foam Insulation. Urea formaldehyde foam insulation may be applied or installed only if:

1. It is installed in exterior sidewalls; and

2. A four mil thick plastic polyethylene vapor barrier or equivalent plastic sheeting vapor barrier is installed between the urea formaldehyde foam insulation and the interior space in all applications.

(c) Flamespread rating. All insulating material shall be installed in compliance with the flamespread rating and smoke density requirements of Sections 2602 and 707 of the Title 24, Part 2.

The California Standards for Insulating Materials, which became effective on January 1, 1982, ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health and safety standards.

Manufacturers must certify that all insulating materials comply with California Standards for Insulating Materials. Builders may not install the types of insulating materials indicated in §118(a) unless the manufacturer has certified the product. Builders and enforcement agencies should use the Department of Consumer Affair's *Consumer Guide and Directory of Certified Insulation Material* to check compliance. Building departments receive a copy of the current directory. If an insulating product is not listed in the most recent edition of the directory, or to purchase a directory, contact the Department of Consumer Affairs Thermal Insulation Program at (916) 574-2065.

Note: Urea Formaldehyde is restricted by §1553 of Title 20. If such products are certified, this is verification that the restrictions of §1553 were met. The restrictions in §118 also apply.

California Standards for Insulating Materials also require that all exposed installations of faced mineral fiber and mineral aggregate insulations must use fire retardant facings. Exposed installations are those where the insulation facings do not touch a ceiling, wall or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing. These installations require insulation that has been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450.

Flame spread ratings and smoke development ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

An Insulation Certificate (IC-1) signed by the insulation installer must be posted in a conspicuous location or made available with the building permit at the time of installation and inspections.

2.2.2 Ceiling Insulation

Requirement

Wood framed ceiling / roof construction assemblies must have at least R-19 insulation or a maximum U-factor of 0.051. Metal framed ceiling/roof constructions must have a U-factor of 0.051 or less. Some areas of the ceiling/roof can fail to meet the requirement as long as other areas exceed the requirement and the weighted average U-factor is 0.51 or less.

§150(a)

(a) Ceiling Insulation. The opaque portions of ceilings separating conditioned spaces from unconditioned spaces or ambient air shall meet the requirements of either 1 or 2 below:

1. Ceilings shall be insulated between wood framing members with insulation resulting in an installed thermal resistance of R-19 or greater for the insulation alone.

ALTERNATIVE to Section 150(a)1.: Insulation which is not penetrated by framing members may meet an R-value equivalent to installing R-19 insulation between wood framing members and accounting for the thermal effects of framing members.

2. The weighted average U-factor of ceilings shall not exceed the U-factor that would result from installing R-19 insulation between wood framing members in the entire ceiling and accounting for the effects of framing members.

R-19 is a mandatory *minimum* level of insulation in a wood frame assembly. This minimum level is typically superseded by the prescriptive requirements. The insulation may be of greater insulating value in certain areas of the ceiling and of lesser insulating value in other areas of the ceiling provided the overall weighted average U-factor does not exceed the equivalent R-19 framed value (maximum U-factor less than or equal to 0.051) as documented on a Form 3R, explained in Appendix G, *Glossary*, *R-Value*.

Insulation not penetrated by framing, such as rigid insulation, can comply with the mandatory R-19 as long as the assembly U-factor is less than or equal to 0.051. The rigid insulation can actually have a rated R-value of less than R-19 and meet this requirement. Compliance can be documented with a Form 3R.

Metal or steel frame assemblies cannot use a Form 3R but have several options available. Use pre-calculated U-factors from Appendix G, pre-calculated metal frame assemblies from Appendix G, calculate the assembly U-factors using form ENV-3 for metal frame assemblies (see Appendix I), or use EZFRAME (see Appendix E) or another method based on the ASHRAE zonal method (1993 *ASHRAE Handbook of Fundamentals*).

Insulation must be certified in compliance with §118 (see Section 2.2.1). Ceiling insulation should extend far enough to the outside walls to cover the top plate. However, insulation should not block eave vents in attics because if the flow of air is blocked, water vapor may condense on the underside of the roof, reducing the insulation's effectiveness and possibly cause structural damage. (See Figure 2-2 and Figure 2-3.)

Where a roof slopes down, insulation may be tapered at the wall. An elevated truss or similar treatment is not needed for full insulation depth at the outside of the wall, but may be desirable. If insulation is tapered for more than three feet from the outside wall, this must be reflected in a weighted average U-factor calculation for the ceiling assembly.

Ceiling insulation levels should correspond to levels specified on the CF-1R and IC-1 (insulation certificate) forms. Although R-19 between wood framing is the minimum mandatory level for ceiling insulation between wood framing members, the package or performance requirement may establish a higher level. Check manufacturers' data (supplied by the builder) for compliance with the requirements of §118.

Fiberglass insulation levels are labeled on the insulation face and should be verified against the levels required by the CF-1R.

Clearances: Incandescent recessed fixtures must be approved for zero-clearance insulation cover (IC-rated). Alternatively, a box built over a recessed fixture so that the fixture is no longer recessed into the insulated ceiling and to provide clearance between the fixture and the insulation is acceptable. Insulation clearances from appliances should meet manufacturer specifications and local code restrictions.

Figure 2-2 – Ceiling Insulation Construction Detail

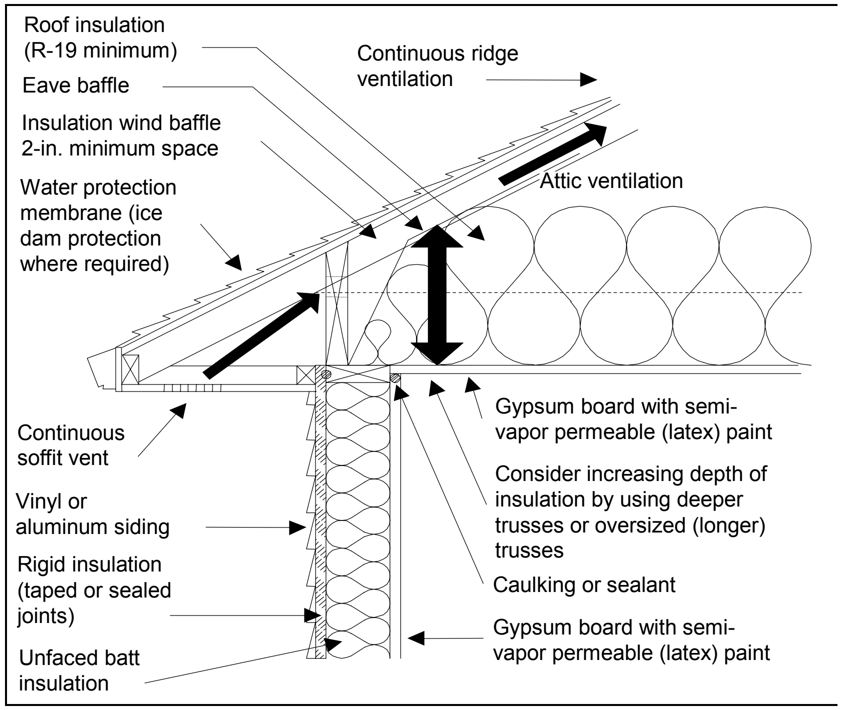
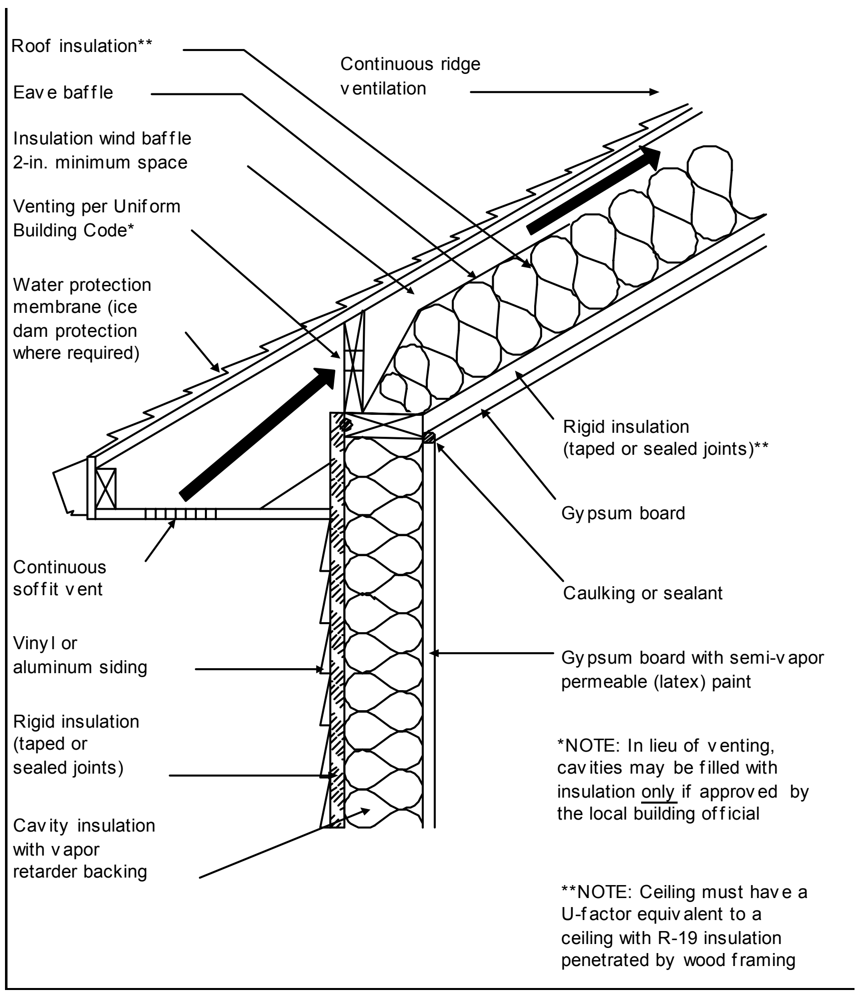


Figure 2-3 – Cathedral Ceiling



Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top (see Figure 2-2 and Figure 2-3).

Loose fill insulation must be blown in evenly and insulation levels must be verified. The insulation level can be verified by checking that the depth of insulation conforms to the manufacturer's coverage chart for achieving the required R-value. Additionally, three criteria the installer must consider are: 1) roof slope, 2) ceiling slope and 3) clearance. The installer should follow the guidelines shown in the construction portion for loose fill insulation (see 2.2.3).

Incandescent fixtures recessed into insulated ceilings must be approved for a zero-clearance insulation cover. Insulation clearances from appliances should meet manufacturer specifications and local code restrictions should be verified.

The Insulation Certificate (IC-1) must be completed and signed by the insulation contractor or general contractor. This form is either posted at the job site or made available during inspection and when completed, a copy of this form must be provided to the first occupant of the building.

Example 2-1 – Application of Mandatory Insulation Levels

Question

A computer method analysis shows that a new house requires R-30 ceiling insulation to comply using the performance approach, but the minimum mandatory insulation level for ceiling insulation is only R-19. Which insulation level should be used?

Answer

R-30. The higher insulation level must be installed for the building to comply.

Question

A small addition to an existing house appears to comply with only R-15 ceiling insulation using a performance approach. Does this insulation level comply with the standard?

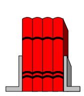
Answer

No. R-15 would not be sufficient because the required minimum ceiling insulation level established by the mandatory measures is R-19.

2.2.3 Loose Fill Insulation

Requirement

When loose fill insulation is installed, it should be blown in evenly. The minimum installed weight per square foot and the minimum depth must conform to the insulation manufacturer's coverage chart for the listed R-value.



§150(b)

(b) ***Loose Fill Insulation.*** *When loose fill insulation is installed, the minimum installed weight per square foot shall conform with the insulation manufacturer's installed design weight per square foot at the manufacturer's labeled R-value.*

When installing loose fill insulation, the following guidelines should be followed:

1. For wood trusses that provide a flat ceiling and a sloped roof, the slope of the roof should be at about 4:12 or greater in order to provide adequate access for installing the insulation. Insulation thickness near the edge of the attic will be reduced with all standard trusses, but this is acceptable as long as the average thickness is adequate to meet the minimum insulation requirement.
2. If the ceiling is sloped (for instance with scissor trusses), loose fill insulation can be used as long as the slope of the ceiling is no more than 4:12. If the ceiling slope is

greater than 4:12 feet, loose fill insulation should not be used unless it incorporates non-water soluble adhesive binder.

3. At the apex of the truss, a clearance of at least 30 inches should be provided to facilitate installation and inspection.

When eave vents are installed, adequate baffling shall be installed at the soffit to deflect the incoming air above the surface of the insulation. Baffles shall be in place at the time of framing inspection.

Follow the above guidelines when inspecting loose fill insulation to ensure adequate coverage, baffling at eave vents and installation in accordance with manufacturer specifications.

2.2.4 Wall Insulation

Requirement

Wood framed walls must have a minimum of R-13 in the cavities between the studs or a maximum U-factor of 0.088. Metal-framed walls must have the equivalent thermal performance of a wood wall with R-13, which is a U-factor of 0.088. There is no minimum insulation requirement for mass walls.

§150(c)

(c) ***Wall Insulation.*** *The opaque portions of frame walls separating conditioned spaces from unconditioned spaces or ambient air shall meet the requirements of either 1 or 2 below:*

1. Wood framed walls shall be insulated between framing members with insulation having an installed thermal resistance of R-13 or greater. Framed foundation walls of heated basements or heated crawl spaces shall be insulated above the adjacent outside ground line with insulation having an installed thermal resistance of at least R-13.

ALTERNATIVE to Section 150(c)1: Insulation which is not penetrated by framing members may meet an R-value equivalent to installing R-13 insulation between wood framing members and accounting for the thermal effects of framing members.

2. The weighted average U-factor of walls shall not exceed the U-factor that would result from installing R-13 insulation between wood framing members and accounting for the effects of framing members.

Compliance for wood frame walls can be met by specifying at least R-13 insulation between framing members (the compliance approach may require a higher level). A U-factor can be determined by using standard values from Appendix I (no Form 3R is required when these values are used). Appendix H contains pre-calculated Form 3Rs for assemblies, including those with rigid insulation (a copy of the form may be submitted with compliance documentation). An assembly U-factor may also be calculated using a Form 3R.

Metal or steel frame assemblies cannot use a Form 3R but have several other options. Use pre-calculated values from Appendix G, pre-calculated metal frame assemblies from Appendix I, calculate the assembly U-factors using form ENV-3 for metal frame assemblies (see Appendix I), or use EZFRAME or another method based on the ASHRAE zonal method (1993 *ASHRAE Handbook of Fundamentals*).

Mass walls that have no framing, such as masonry or concrete exterior walls, do not have to meet the R-13 minumum insulation requirement (see Figure 2-4).

Framed foundation walls of heated basements or heated crawl spaces must be insulated above the adjacent outside ground line with at least R-13 insulation.

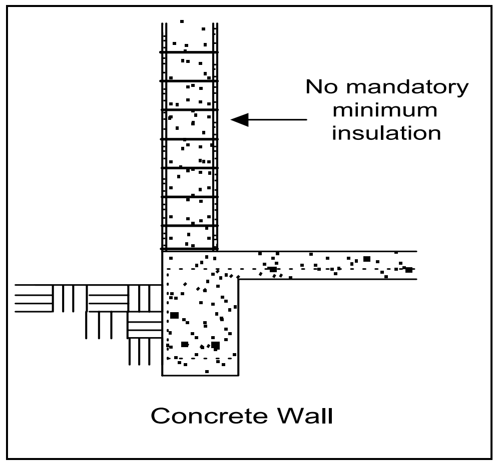
Insulation not penetrated by framing members, such as rigid insulation over the face of framing, may meet an R-value equivalent to a wall with R-13 insulation adjusted for the effects of wood framing 16" o. c. (maximum U-factor 0.088). Documenting equivalency for a wall assembly may also be shown on the Form-3R.

Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the overall weighted average U-factor does not exceed the equivalent R-13 framed value (maximum U-factor less than or equal to 0.088).

U-factors for concrete and masonry walls can be determined using the simplified masonry calculation method and Form 3R (see Appendix I).

Note: An existing structure, such as a garage, with R-11 framed walls that comply with performance approach, need not comply with the mandatory R-13 wall insulation. The addition must achieve compliance under an energy budget approach with R-11 insulation in these walls. See Chapter 7.

Figure 2-4 – Concrete Wall Insulation



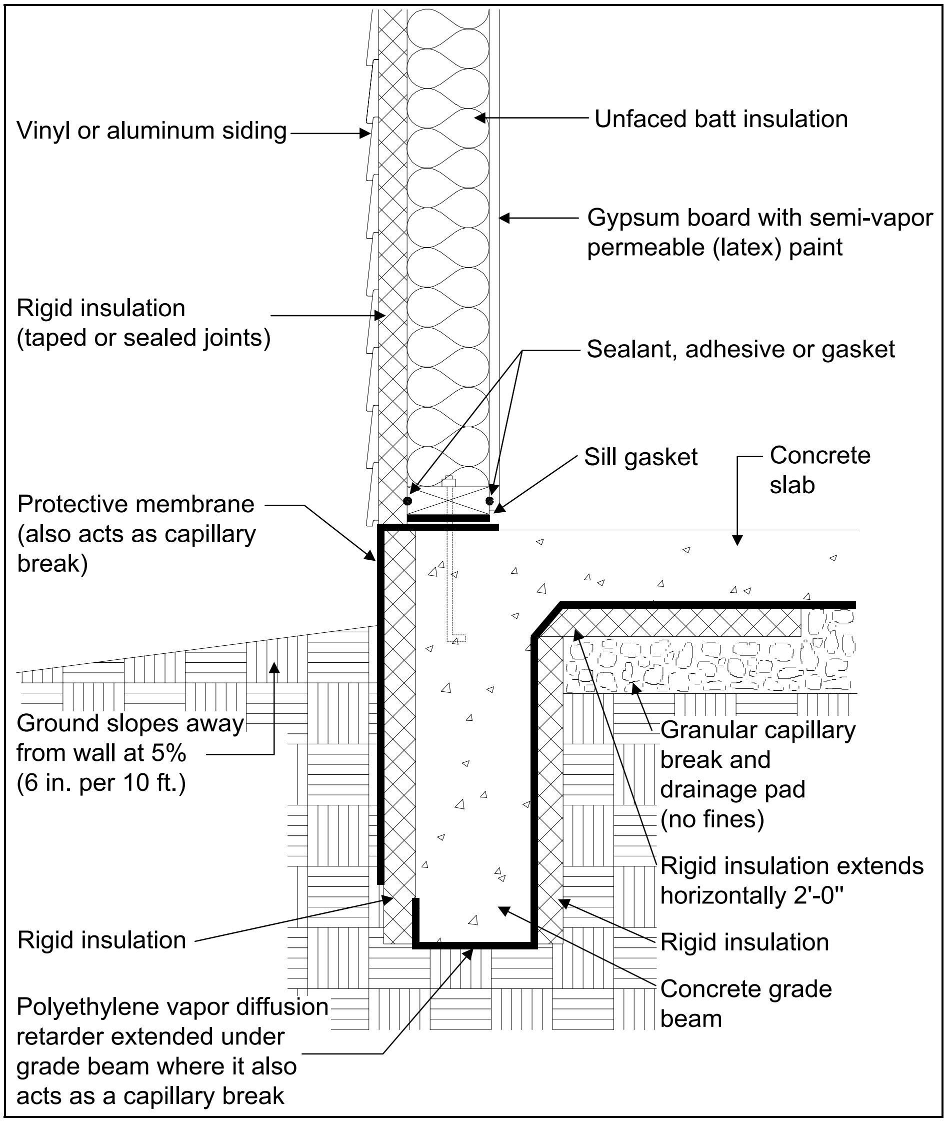


Figure 2-5 – Wall Construction Detail

Wood-Framed Wall with Vinyl or Aluminum Siding, Mandatory Minimum R-13 Insulation or U-factor < 0.088

A change from wood framing to metal framing can significantly affect compliance. These two framing types are not interchangeable. Metal frame wall construction requires rigid insulation in order to meet the mandatory minimum wall insulation level (U-factor less than or equal to 0.088), Therefore, if compliance calculations indicate wood frame construction, either the compliance calculations must be redone with the correct assembly, or a metal frame construction with an equivalent U-factor is required (R-5 rigid insulation with R-15 batt in 2x4 metal framing, 24” o.c.; R-4 rigid insulation with R-19 batt in a 2x6, 24” o.c.).

Rim joists between the stories of a multi-story building are part of the wall and must be insulated to the same level as the wall.

Wall insulation levels should correspond to levels specified on the CF-1R and IC-1 (Insulation Certificate) forms.

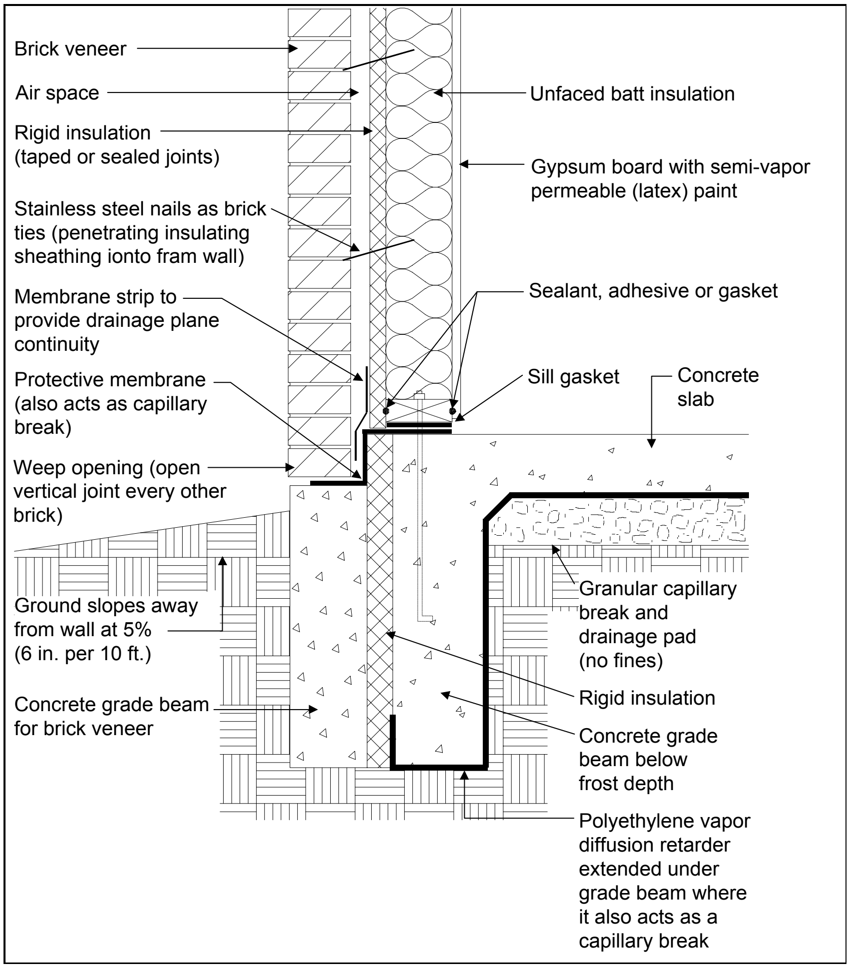
R-13 between wood framing is the minimum mandatory requirement; the package or performance requirement may establish a higher level. This requirement can be met with R-13 cavity insulation in a wood framed wall or with a weighted average U-factor that is equivalent (maximum U-factor 0.088).

Metal framed walls will require rigid insulation to achieve the maximum 0.088 U-factor.

Mass walls that have no framing, such as masonry or concrete, are not required to meet this minimum requirement but may have other insulation requirements as indicated on the CF-1R.

Figure 2-6 – Brick Wall Construction Details

Wood-Framed Wall with Brick Veneer, Mandatory Minimum R-13 Insulation or U-factor ≤ 0.088



The Insulation Certificate (IC-1) must also be completed, signed by the insulation contractor or general contractor. The insulation levels, including rigid insulation, must be consistent with information on the CF-1R. This form is either posted at the job site or made available during inspection and when completed, a copy of this form must be provided to the first occupant of the building.

The R-value of different types of rigid insulation can vary significantly. If rigid insulation is specified on the plans, verify that the type installed is consistent with those specifications.

Because it is difficult to inspect wall insulation between tub/shower enclosures after the enclosure is installed, insulation of these wall sections should be inspected during the framing inspection.

Batt insulation should fill the wall cavity evenly and the kraft or foil facing should be installed per manufacturer recommendations to minimize air leakage and avoid sagging in the insulation.

Wall insulation should extend into the perimeter floor joist (rim joist) cavities along the same plane as the wall.

If a vapor barrier is required, it must face the conditioned space on all installations.

Example 2-2 – Wall Insulation Scenarios

Question

Do new residential buildings or additions consisting of block walls (for example, converting a garage into living space) have to comply with the R-13 minimum wall insulation requirement? If not, what insulation R-value do they need?

Answer

No, the mandatory wall insulation requirement for R-13 applies to frame walls only. The amount of insulation needed, if any, will vary depending on the compliance approach selected. Performance compliance may not require any additional insulation if compliance is achieved without insulation in that space. Prescriptive compliance may require some level of insulation, depending on the climate zone, package selected, and whether the walls are light (block) or heavy mass. Use *Residential Manual* Appendix B, Materials Reference and Appendix I, Framing Calculations, to determine the R-value of the mass wall alone. If additional insulation is required, it must be integral with the wall or installed on the outside of the mass wall (Energy Efficiency Standards, §151(f), Tables No. 1-Z1 through 1-Z16, Note 2).

Question

If I build a steel framed wall with R-13 insulation between the framing, does this comply with mandatory wall insulation requirements?

Answer

No. The wall must have the equivalent U-factor as a wood framed wall with R-13 insulation, which is a maximum of 0.088. To determine if a steel frame assembly meets this U-factor, you have several options. Use one of the pre-calculated assemblies found in Appendix I of the *Residential Manual*. Calculate the U-factor using an ENV-3 for steel frame construction (from Appendix I or from the Nonresidential Manual. Calculate the U-factor using EZFRAME or another method based on ASHRAE zone method.

You cannot use any of the following to document the U-factor of a steel frame wall: Form 3R or any parallel path method, values from Appendix G, Table G-18, in the *Residential Manual* which exceed 0.088 U-factor, or any U-factor which is more than 10% different than values found in or calculated using one of the above referenced sources.

2.2.5 Raised Floor Insulation

Requirement

Wood framed floors must have a minimum of R-13 insulation installed between framing members or the construction must have a U-factor of 0.064 or less. Some areas of the floor can have a U-factor that fails the requirements as long as other areas have a U-factor that exceeds the requirements and the area weighted average U-factor is 0.064 or less. There is an exception to this requirement for qualifying controlled ventilation crawlspaces.

§150(d)

(d) ***Raised Floor Insulation.*** *Raised floors separating conditioned space from unconditioned space shall meet the requirements of either 1 or 2 below:*

1. *Floors shall be insulated between wood framing members with insulation having an installed thermal resistance of R-13 or greater.*

2. *The weighted average U-factor of floor assemblies shall not exceed the U-factor that would result from installing R-13 insulation between wood framing members and accounting for the effects of framing members.*

ALTERNATIVE to §150(d) 1. and 2.: Raised floor insulation may be omitted if the foundation walls are insulated to meet the wall insulation minimums shown in Tables No. 1-Z1 through 1-Z16, a vapor barrier is placed over the entire floor of the crawl *space, and vents are fitted with automatically operated louvers that are temperature actuated.*

The raised floor insulation may be of greater insulating value in some areas and of lesser insulating value in other areas of the raised floor, provided the overall weighted average U-factor does not exceed the equivalent R-13 framed value (maximum U-factor less than or equal to 0.064).

Insulation that is not penetrated by framing members, such as rigid insulation over the face of framing, may meet a U-factor equivalent to a wood framed floor with R-13 insulation adjusted for the effects of wood framing (U-factor less than or equal to 0.064). Documenting equivalence may also be shown using Form-3R (see Appendix G, *Glossary, R-Value)*.

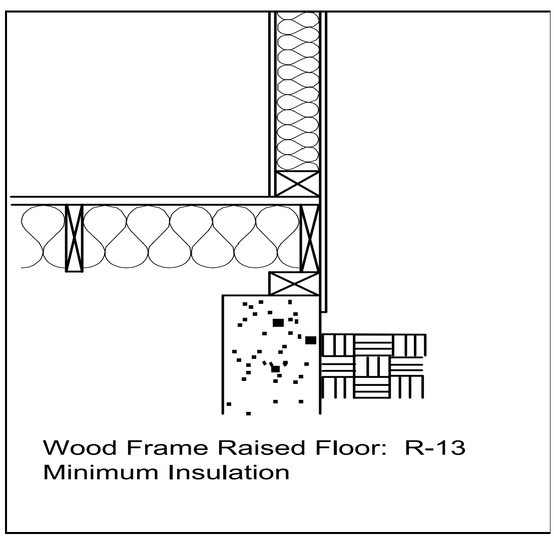
Note: When residences are modeled using an approved computer method (see Chapter 5), R-6 is added to the floor construction to approximate the effect of crawlspace. The maximum raised floor U-factor of 0.064 cannot be met by including the effects of the R-6 crawl space.

An alternative to meeting the minimum raised floor insulation level is to meet all criteria of Controlled Ventilation Crawl Spaces described in Section 8.6. If all eligibility and installation criteria for a controlled ventilated crawl space are met, raised floors above the controlled ventilation crawl space need not meet the minimum insulation requirement.

If the building has a wood raised floor, a minimum of R-13 insulation is required (see Figure 2-7). Check the CF-1R for the required insulation level. The IC-1 must be completed and signed by the installing contractor or the project's general contractor. The insulation levels specified on both forms must be consistent.

For proper installation, floor insulation should be installed in contact with the subfloor, stapled to the floor joists and supported with netting stapled to the underside of floor joists, wires running perpendicular to the joists, or other suitable means. Floor insulation should not cover foundation vents.

Figure 2-7 – Raised Floor Insulation



2.2.6 Slab Edge Insulation

Requirement

When slab edge insulation is required by the *Standards*, the insulation material must be suitable for the application with a water absorption rate no greater than 0.3% and a vapor permeance no greater than 2.0 perm/inch. The insulation must also be protected from physical and UV degradation.

§150(l)

(l) *Slab Edge Insulation. Material used for slab edge insulation shall meet the following minimum specifications:*

a. Water absorption rate no greater than 0.3 percent when tested in accordance with ASTM-C-271-94.

b. Water vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM-E-96-95.

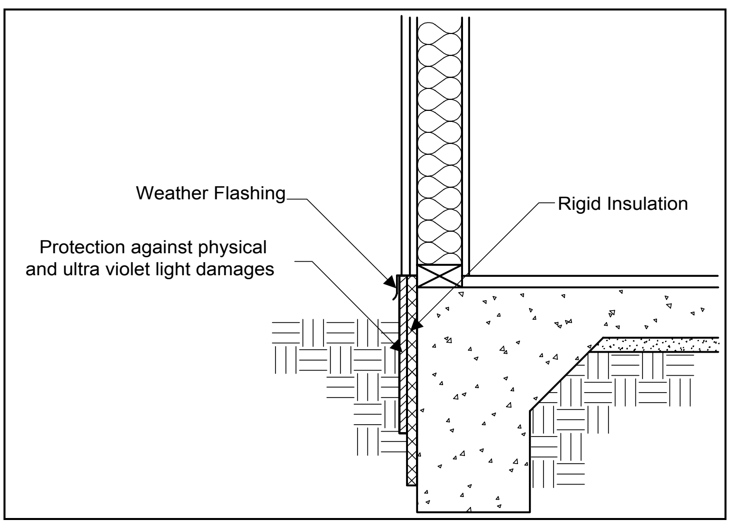
c. Concrete slab perimeter insulation must be protected from physical damage and ultra violet light deterioration.

Slab edge insulation is not mandatory but may be required by the prescriptive package (see Chapter 3), or used for credit in the compliance calculations. The mandatory measures address the material requirements when used for compliance.

Slab edge insulation must be installed with heated slabs. This is not part of the mandatory requirements of the *Standards*, but rather is an eligibility criterion for hydronic heating systems with coils in the slab. Slab edge insulation installed with hydronic heating systems is considered energy neutral and is not modeled in performance calculations. See Section 8.8 for more details on radiant floor heating systems.

Slab edge insulation reduces heat loss through the slab perimeter. When required, as indicated on the CF-1R, the material used must meet the above specifications. An example of an insulating material that meets these specifications is smooth-skin extruded polystyrene.

Figure 2-8 – Slab Edge Insulation



If slab edge insulation is indicated on the CF-1R, it is inspected during the foundation inspection. The IC-1 must also be completed and signed by the installing contractor or the project's general contractor. The insulation levels specified on both forms must be consistent.

The R-value and water absorption / permeance properties should be stamped on the insulation, or the installing contractor should provide manufacturer's literature to verify that these requirements are satisfied.

The slab edge must be protected from physical damage and ultra-violet light deterioration when installed on the exterior footing.

2.2.7 Insulation in Existing Buildings

Requirement

This mandatory requirement deals with the installation of insulation in existing buildings. When insulation is retrofitted in existing attics, the total insulation must be R-30 or greater in areas with less than 5,000 heating degree-days and R-38 or greater in areas with 5,000 heating degree-days or more. When water heaters are insulated, at least R-12 insulation must be used. And, when ducts are insulated, at least R-4.2 insulation must be installed.

§118(d)

(d) ***Installation of Insulation in Existing Buildings**. Insulation installed in an existing attic, or on an existing duct or water heater, shall comply with the applicable requirements of this subsection. If a contractor installs the insulation, the contractor shall certify to the customer, in writing, that the insulation meets the applicable requirements of this subsection.*

*1. **Attics**. If insulation is installed in the existing attic of a low-rise residential building, the R-value of the total amount of insulation (after addition of insulation to the amount, if any, already in the attic) shall be at least R-30, if the building is located in an area that has less than 5,000 heating degree days, or R-38 if the building is located in an area that has 5,000 heating degree days or more.*

EXCEPTION to Section 118(d)1.: Where the accessible space in the attic is not large enough to accommodate the required R-value, the entire accessible space shall be filled with insulation provided such installation does not violate Section 1505.3 of Title 24, Part 2.

2. Water Heaters. If external insulation is installed on an existing unfired water storage tank or on an existing back up tank for a solar water heating systems, it shall have an R-value of at least R-12, or the heat loss of the tank surface based on an 80°F water-air temperature difference shall be less than 6.5 Btus per hour per square foot.

3. Ducts. If insulation is installed on an existing space conditioning duct, it shall comply with Section 604 of the CMC.

Attic Insulation

When insulation is installed in an existing, accessible attic it must meet or exceed:

- R-30 if the building is located in an area that has less than 5,000 heating degree days; or
- R-38 if the building is located in an area that has 5,000 heating degree-days or more.

Heating degree-days for 641 California locations can be found in Appendix C.

Water Heater Storage Tank Insulation

There are no requirements for typical storage water heaters. If a permit applicant is adding insulation to an unfired water heater (e.g., holding tank for a boiler) or an existing back-up tank for a solar water heating system, at least R-12 must be added.

Duct Insulation

When a permit applicant is adding insulation to an existing duct system, R-4.2 insulation is required, unless cooling system ducts are installed on the roof or heating system ducts are installed on the roof in an area with more than 8,000 heating degree days where a minimum of R-6.3 insulation is required by the CMC. Heating degree days for 641 California locations can be found in Appendix C. See Section 2.5.7 for installation guidelines.

Installation of ceiling insulation should match guidelines contained in discussions under Sections 2.2.2 Ceiling Insulation, 2.2.3 Loose Fill Insulation, and 2.2.1 Certification of Insulating Material.

An Insulation Certificate (IC-1) must be completed, signed by the insulation contractor or general contractor. This form can either be posted at the job site or given to the building owner.

2.3 Fenestration / Exterior Doors

§101(b)

FENESTRATION PRODUCT is any transparent or translucent material plus any sash, frame, mullions and dividers, in the envelope of a building, including, but not limited to, windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one half of the door area.

FENESTRATION SYSTEM means a collection of fenestration products included in the design of a building. (See "fenestration product")

FIELD-FABRICATED FENESTRATION PRODUCT OR EXTERIOR DOOR is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

MANUFACTURED FENESTRATION PRODUCT is a fenestration product typically assembled before delivery to a job site. A "knocked-down" or partially assembled product sold as a fenestration product must be considered a manufactured fenestration product and meet the rating and labeling requirements for manufactured fenestration products.

SITE-BUILT FENESTRATION PRODUCTS are fenestration products designed to be field-glazed or field assembled units comprised of specified framing and glazing components. Site-built fenestration is eligible for certification under NFRC 100-SB, and may include both vertical glazing and horizontal glazing.

§116

(a) Certification of Fenestration Products and Exterior Doors. Any fenestration product and exterior door, other than field-fabricated fenestration products and field-fabricated exterior doors, may be installed only if the manufacturer has certified to the Commission, or if an independent certifying organization approved by the Commission has certified, that the product complies with all of the applicable requirements of this subsection.

a. Air Leakage. Manufactured fenestration products and exterior doors shall have air infiltration rates not exceeding 0.3 cfm/ft² of window area, 0.3 cfm/ft² of door area for residential doors, 0.3 cfm/ft² of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft² for nonresidential double doors (swinging), when tested according to NFRC-400-95 or ASTM E283-91 at a pressure differential of 75 pascals or 1.57 pounds/ft², incorporated herein by reference.

b. U-factor and SHGC. Fenestration products shall:

A. Be certified for overall U-factors as rated in accordance with the National Fenestration Rating Council's NFRC 100 (1997) and be certified for overall SHGC, as rated in accordance with the National Fenestration Rating

Council's NFRC 200 (1995), incorporated herein by reference, or such values shall be certified in accordance with Tables 1-D and 1E and labeled as set forth in Section 10-111; and

B. Have a temporary label or label certificate (for site-built products) meeting the requirements of Section 10-111(a)(1), not to be removed before inspection by the enforcement agency, listing the certified U-factor and SHGC, and certifying that the air leakage requirements of Section 116(a)1. are met for each product line; and

C. Have a permanent label or label certificate (for site-built products) meeting the requirements of Section 10-111(a)(2) if the product is rated using NFRC procedures.

EXCEPTION to Section 116(a): Fenestration products removed and reinstalled as part of a building alteration or addition.

…

EXCEPTION 3 to Section 116 (a) 2:Skylights and site-assembled horizontal glazing shall have SHGC values and U-factors determined in accordance with NFRC procedures or default values set forth in Appendix I of the Nonresidential ACM Manual. Documentation shall be provided as set forth in Appendix I of the Nonresidential ACM Manual.

(b) Installation of Field-Fabricated Fenestration Products and Exterior Doors. Field-fabricated fenestration products and exterior doors shall be caulked between the fenestration products or exterior door and the building, and shall be weatherstripped.

EXCEPTION to Section 116(b): Unframed glass doors and fire doors.

Table 2-2 – Default Fenestration Product U-factors (From Table 1-D of §116 of the Standards)

Frame Type[1]	***Product Type***[2]	***Single Pane U-factor***	***Double Pane U-factor***[3]
Metal	Operable	1.28	0.87
Metal	Fixed	1.19	0.72
Metal	Greenhouse/Garden window	2.26	1.40
Metal	Doors	1.25	0.85
Metal	Skylight	1.72	0.94
Metal, Thermal Break	Operable		0.71
Metal, Thermal Break	Fixed		0.60
Metal, Thermal Break	Greenhouse/Garden window		1.12
Metal, Thermal Break	Doors		0.64
Metal, Thermal Break	Skylight		0.80
Non-Metal	Operable	0.99	0.60
Non-Metal	Fixed	1.04	0.57
Non-Metal	Doors	0.99	0.55
Non-Metal	Greenhouse/Garden windows	1.94	1.06
Non-Metal	Skylight	1.47	0.68

1 Metal includes any field-fabricated product with metal cladding. Non-metal framed manufactured fenestration products with metal cladding must add 0.04 to the listed U-factor. Non-Metal frame types can include metal fasteners, hardware, and door thresholds. Thermal break product design characteristics are:

a. The material used as the thermal break must have a thermal conductivity of not more than 3.6 Btu-inch/hr/ft^2/°F,

b. The thermal break must produce a gap of not less than 0.210”, and

c. All metal members of the fenestration product exposed to interior and exterior air must incorporate a thermal break meeting the criteria in a and b above.

In addition, the fenestration product must be clearly labeled by the manufacturer that it qualifies as a thermally broken product in accordance with this standard.

The values for non-metal can be used for unframed windows.

2 Glass Block may use the values for double pane windows of the same frame type used with the glass block.

3 For all dual glazed fenestration products, adjust the listed U-factors as follows:

a. Subtract 0.05 for spacers of 7/16” or wider.

b. Subtract 0.05 for products certified by the manufacturer as low-E glazing.

c. Add 0.05 for products with dividers between panes if spacer is less than 7/16” wide.

d. Add 0.05 to any product with true divided light (dividers through the panes).

Table 2-3 – Default Solar Heat Gain Coefficients (From Table 1-E of §116 of the Standards)

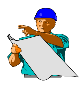
Frame Type	***Product***[1]	***Glazing***	***Single Pane***	***Double Pane***
Metal	Operable	Clear	0.80	0.70
	Fixed	Clear	0.83	0.73
	Operable	Tinted	0.67	0.59
	Fixed	Tinted	0.68	0.60
Metal, Thermal Break	Operable	Clear	0.72	0.63
	Fixed	Clear	0.78	0.69
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.65	0.57
Non-Metal	Operable	Clear	0.74	0.65
	Fixed	Clear	0.76	0.67
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.63	0.55

1 The values for non-metal can be used for unframed windows. Glass Block may use the values for double pane windows of the same frame type used with the glass block

The National Fenestration Rating Council (NFRC) publishes the Certified Product Directory, containing NFRC certified U-factors and SHGC for thousands of products. This directory can be purchased by contacting:

NFRC
1300 Spring Street, Suite 120
Silver Springs, MD 20901
(301) 589-6372

Compliance calculations can use NFRC labeled product data or default SHGC and U-factors depending on the fenestration category (see Table 2-4 and Table 2-5. There are three main categories of fenestration products – field-fabricated fenestration, manufactured fenestration, and site-built fenestration. See 8.4.1 for definitions of these categories. The CF-6R must be completed by the installer, listing all the fenestration products installed in the dwelling unit.



Field-fabricated Products. Field-fabricated products are required to limit air leakage by weatherstripping, caulking, or some other appropriate means as described below in “Joints and Other Openings.” Field-fabricated products may only use default values (from Table 2-2 and Table 2-3) for determining U-factors and SHGC. Temporary and permanent labels are not required for field-fabricated products.

Manufactured Fenestration and Site-built Fenestration. Fenestration products must have a temporary label indicating the U-factor and SHGC based on either the *CEC Default* or *NFRC Rating Procedures.* Site built fenestration products may have a 'label certificate' in accordance with NFRC 100-SB instead of a label. Site built fenestration products not rated in accordance with NFRC 100-SB may have a 'label certificate' provided by the manufacturer that includes the same information as provided in the NFRC 100-SB label certificate instead of a label.

Each manufactured fenestration product must:

- have a temporary label, not to be removed before inspection by the enforcement agency, listing the certified U-factor, SHGC, and certifying that the air infiltration requirements of §116 are met (see Figure 2-9); and
- have a permanent label listing, the U-factor, certifying organization, and rating procedures or a label to allow tracking back to the original certification information on file with the certifying organization.

The U-factor and SHGC values on the window label must be less than, or equal to, the values used for compliance and documented on the CF-1R.

Exterior Doors. Exterior doors are required to meet the following requirements of the *Standards*:

- Manufactured exterior doors must be certified as meeting an air leakage rate of 0.3 cfm/ft² of door area.
- Comply with the requirements of §116(b) and §117, as described below in “Joints and Other Openings.”

Any door with more than one half of the door area consisting of glass is considered a fenestration product. The standards define an exterior door as:

EXTERIOR DOOR is a door through an exterior partition that is opaque or has a glazed area that is less than or equal to one-half of the door area. Doors with a glazed area of more than one half of the door area are treated as a fenestration product.

Table 2-4 – Methods for Determining U-factors

U-factor Determination Method	Fenestration Category: Manufactured Windows	Fenestration Category: Site-Built Fenestration	Fenestration Category: Field-Fabricated Fenestration
NFRC 100 (1997)	✓	✓	
NFRC 100-SB (2000)		✓	
Table 2-2 (*Standard* Table 1-D)	✓	✓	✓

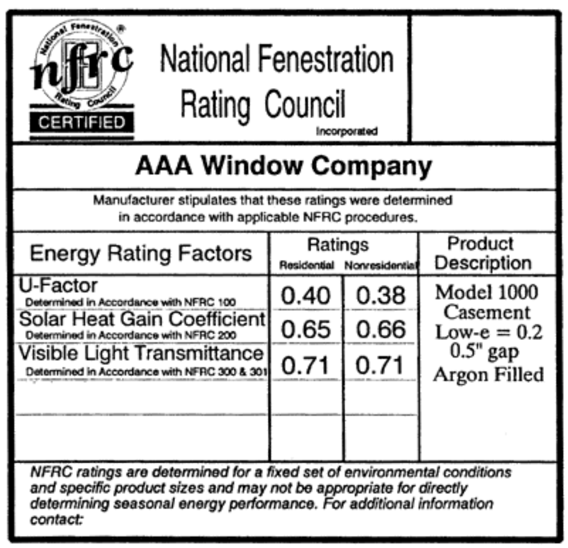
Table 2-5 – Methods for Determining Solar Heat Gain Coefficients

SHGC Determination Method	Fenestration Category: Manufactured Windows	Fenestration Category: Site-Built Fenestration	Fenestration Category: Field-Fabricated Fenestration
NFRC 200 (1995)	✓	✓	
NFRC 100-SB (2000)		✓	
Table 2-3 (*Standard* Table 1-E)	✓	✓	✓

Fenestration and shading products play a major role in not only the building's energy use but can affect the operation of the HVAC system and the comfort of the occupants. Check all installed fenestration including windows, doors with over one-half glass, and glazed skylights.

Check the CF-6R completed by the installer and compare it to the temporary label. All fenestration products must have a temporary label indicating the U-factor, Solar Heat Gain Coefficient (SHGC) and certification of air infiltration requirements (only field-fabricated products are exempt from labeling requirements).

Figure 2-9 – Temporary Label



The label may separately list the U-factor, SHGC, and visible light transmission for residential and nonresidential window sizes. The residential U-factor and SHGC data is all that matters with the low-rise residential standards. The nonresidential data can be ignored and visible light transmission is not regulated by the *Standards*.

Example 2-3 – Mandatory Measures Applied to Fenestration

Question

My home will have a combination of window types, including fixed, operable, wood, metal, etc. None of the windows are rated by NFRC. What are the options for showing compliance with the *Standards*.

Answer

Since none of the windows are rated by NFRC, you must select U-factors and SHGC values from the default tables (see Table 2-2 and Table 2-3). If any of the U-factors or SHGCs do not comply with the prescriptive requirements, you must use the performance method (see chapter 5). To simplify data entry into the compliance software, you can choose the value from Table 2-2 that is the highest of any of the windows, and use this for all windows. However, you must use the appropriate SHGC from Table 2-3 for each window type individually. However, the latter approach will make it more difficult to comply with the *Standards*.

Question

When windows are labeled with a default value, are there any special requirements that apply to the label?

Answer

There are two criteria that apply to fenestration products labeled with default values. First, the Administrative Regulations (§10-111) require that the words "CEC Default U-factor" and "CEC Default SHGC" appear on the temporary label in front of or before the U-factor or SHGC (i.e., not in a footnote). Second, the U-factor and SHGC for the specific product must be listed. If multiple values are listed on the label, the manufacturer must identify, in a permanent manner, the appropriate value for the labeled product. Marking the correct value may be done in the following ways only:

- Circle the correct U-factor and SHGC (permanent ink).
- Black out all values except the correct U-factor and SHGC (permanent ink).
- Make a hole punch next to the appropriate values.

Question

What U-factor do I use for glass block? What solar heat gain coefficient do I use for clear glass block? Does it need a label?

Answer

For glass block, use the U-factor and SHGC values from Table 2-2 and Table 2-3 for double pane glass for the frame type in which the glass blocks are installed. Unframed glass block is the same as unframed window, which is the same as non-metal fixed frame. The U-factor for unframed glass block is therefore 0.57. The SHGC depends on whether the glass block is tinted. For this example, the glass block is clear, therefore the SHGC is 0.67. Glass block is considered a field-fabricated product and therefore does not need a label.

Question

Is there a default U-factor for the glass in sunrooms?

Answer

For the horizontal portion of the sunroom, use the U-factor for skylights. For the vertical portion, use the U-factors for either fixed, operable or doors, as appropriate. Use either default or NFRC-rated U-factors. As a simplifying alternative, the manufacturer may label the entire sunroom with the highest U-factor of any of the individual fenestration types within the assembly.

Question

How are French doors treated in compliance documentation, for example the U-factor and dimensions? How can I determine a solar heat gain coefficient for French doors when 50 percent or more of the door area is glass?

Answer

French doors with 50 percent or more of the door area in glass are defined as fenestration products (101, Exterior Door) and are covered by the National Fenestration Rating Council (NFRC) Rating and Certification Program. You may use either an NFRC-rated U-factor or a default doors U-factor. The fenestration area for compliance documentation is the entire rough opening of the door (not just the glass area).

The solar heat gain coefficient (SHGC) for French doors may be determined in one of two ways:

1. Use the NFRC rated and labeled SHGC.
2. Refer to Table 2-3. The SHGCs in this table have been pre-calculated based upon glazing type, framing type, and interior shade type.

If a door has 50% or less of its surface area made up of glass, either the entire door may be treated as fenestration or the door may be treated as a combination of opaque surface area and the glass area (glass plus a two-inch frame extending on all sides). If the entire door is treated as fenestration, either NFRC ratings or default table values may be used for determining U-factor and SHGC. If the door is treated as a combination of opaque surface area and glass area, the U-factor and the SHGC for the glass area is taken from the default tables (the remaining door area is modeled as an opaque surface). Changing a door without any other changes to an existing building is considered a replacement of a fenestration product, and therefore U-factor or SHGC requirements are not applicable.

Question

As a manufacturer of fenestration products, I place a temporary label with the air infiltration rates on my products (§116(a)). Can you clarify which products must be tested and certified?

Answer

Each product line must be tested and certified for air infiltration rates. Features such as weather seal, frame design, operator type, and direction of operation all effect air leakage. Every product must have a temporary label certifying that the air infiltration requirements are met. This temporary label may be combined with the temporary U-factor label.

Question

Is a custom window “field-fabricated” for purposes of meeting air infiltration requirements?

Answer

No. Most custom windows are manufactured and delivered to the site either completely assembled or “knocked down”, which means they are a manufactured product. A window is considered field fabricated when the windows are assembled at the building site from the various elements that are not sold together as a fenestration product (i.e., glazing, framing and weatherstripping). As stated in the definition, “field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits, and curtainwalls).”

2.4 Infiltration and Moisture Control

Note: Infiltration through fenestration products is addressed in the previous section.

2.4.1 Joints and Other Openings

§117

(a) Joints and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weatherstripped, or otherwise sealed to limit infiltration and exfiltration.

Air leakage through cracks around windows, doors, walls, roofs and floors can result in higher energy use for home heating and cooling than necessary. The *Standards* contain a number of requirements to control infiltration and exfiltration.

The following openings in the building envelope must be caulked, gasketed, weather-stripped or otherwise sealed (see Figure 2-10):

- Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and unconditioned space, between attic access and conditioned space, and between wall sole plates, floors, exterior panels and all siding materials;
- Openings for plumbing, electricity, and gas lines in exterior walls, ceilings and floors;
- Openings in the attic floor (such as where ceiling panels meet interior and exterior walls and masonry fireplaces); and
- Exhaust duct from a clothes dryer needs to have a damper; and all other such openings in the building envelope.

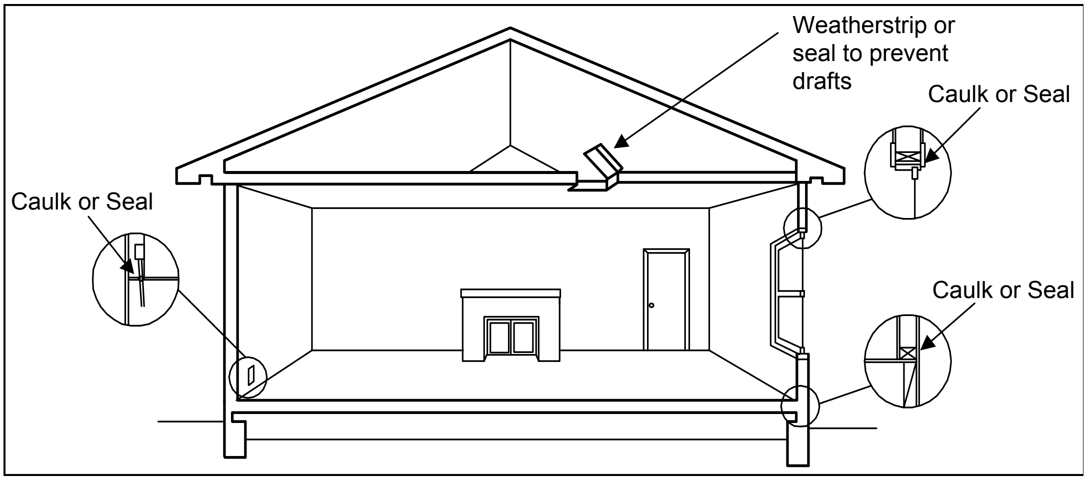
Alternative approved techniques may be used to meet the mandatory caulking requirements for exterior walls. These include, but are not limited to:

- Continuous stucco
- Caulking and taping all joints between wall components (e.g., between slats in wood slat walls)
- Building wraps
- Rigid wall insulation

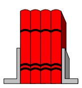
Openings in exterior walls are often needed to accommodate gas, plumbing or electrical lines. Any openings in the building envelope separating conditioned space from unconditioned space must be sealed to prevent air leakage. A proper seal can be verified by checking that the opening is continuously caulked all around and that no light can be seen around the opening. Caulking must also be applied between the bottom plate of the wall framing and the subfloor (see Figure 2-10).

Weather-stripping is required on all operable windows and doors. This includes doors between the garage and the house, between interior HVAC closets and conditioned space, and between the attic access and conditioned space.

Figure 2-10 – Caulking and Weather Stripping



2.4.2 Vapor Barrier



§150(g), 101(b)

(g) ***Vapor Barriers.*** *In Climate Zones 14 and 16 as shown in Figure No. 1-A, a vapor barrier shall be installed on the conditioned space side of all insulation in all exterior walls, unvented attics, and unvented crawl spaces to protect insulation from condensation.*

If a building has a controlled ventilation crawl space (CVC), a vapor barrier shall be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation, as specified in the ALTERNATIVE to Section 150(d).

VAPOR BARRIER is a material that has a permeance of one perm or less and that provides resistance to the transmission of water vapor.

A vapor barrier or retarder is a special covering over framing and insulation that protects the wall assembly components from possible damage due to moisture buildup. When moisture gravitates from inside the house toward the outdoors it can condense, causing the insulation to lose its effectiveness.

In Climate Zones 14 and 16 only, a continuous vapor barrier, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the floors of unvented attics, and on floors over unvented crawl spaces to protect insulation from condensation. If a building has a controlled ventilation crawl space (see Section 8.6), a vapor barrier shall be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation.

The *Standards* define a vapor barrier as material with a permeance of one perm or less. A perm is a measure of resistance to the transmission of water vapors and is equal to one grain of water vapor transmitted per square foot per hour per inch of mercury pressure difference. The *Commission* has determined that interior painted surfaces may qualify for meeting the vapor barrier requirement if the paint product is tested to have a rating of at least one perm. For all types of vapor barriers, care should be taken to seal penetrations such as electric outlets on exterior walls.

Products such as a continuous polyethylene sheet or wall board with foil backing qualifies as vapor barrier, if according to the appropriate testing procedure, it meets the vapor barrier permeance rating of one perm or less. Kraft paper backing on batt insulation qualifies if the paper backing meets the vapor barrier permeance rating, and is properly installed. For proper installation, the Kraft paper should be installed per manufacturer instructions.

If a building is being constructed in climate zone 14 or 16, a continuous vapor barrier is required. One of several products should be indicated on the plans to comply with this requirement. Acceptable products include:

- Continuous polyethylene sheet,
- Wall board with foil backing,
- Kraft facing, or
- Any product that has appropriate test data verifying a moisture migration resistance of one perm or less.

Kraft paper backing on batt insulation, under certain circumstances, may be used to meet the continuous vapor barrier requirement. Specifically, the paper backing must meet the vapor barrier permeance rating and the product must be installed properly. For proper installation of batt insulation with Kraft paper backing:

1. Kraft paper should *not* be stapled to the sides of framing members; instead, the Kraft paper tabs on each side of the insulation batt must be fastened to the face of the conditioned side of the framing member, and
2. At the ends of the insulated cavity, the Kraft paper must overlap the framing members to create a continuous barrier at the wall cavity.

2.4.3 Special Infiltration Barrier

The mandatory requirement for infiltration barriers is no longer applicable. The prescriptive packages (Package B) used to require a special infiltration barrier in some climates. Package B was deleted with the 2001 update to the *Standards* and none of the prescriptive packages now require a special infiltration barrier.

§150(f)

Infiltration Barrier. If an infiltration barrier is installed to meet the requirements of Section 151, it must have an air porosity of less than 5 ft³ per hour per square foot per inch of mercury pressure difference when tested in accordance with the requirements of ASTM E283-91. If a vapor barrier functions as an infiltration barrier it shall be located on the conditioned side of the exterior framing.

2.4.4 Fireplaces, Decorative Gas Appliances and Gas Logs

§150(e) has requirements to limit infiltration associated with fireplaces, decorative gas appliances and gas logs. The code language is shown below.

§150(e)

1. If a masonry or factory-built fireplace is installed, it shall have the following:

A. Closable metal or glass doors covering the entire opening of the firebox;

B. A combustion air intake to draw air from the outside of the building directly into the firebox, which is at least 6-square inches in area and is equipped with a readily accessible, operable, and tight-fitting damper or combustion air control device; and

EXCEPTION to Section 150(e)1.B.: An outside combustion air intake is not required if the fireplace will be installed over concrete slab flooring and the fireplace will not be located on an exterior wall.

C. A flue damper with a readily accessible control.

EXCEPTION to Section 150(e)1.C.: When a gas log, log lighter, or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.

2. *Continuous burning pilot lights and the use of indoor air for cooling a firebox jacket, when that indoor air is vented to the outside of the building, are prohibited.*

Because conditioned air can escape through a fireplace chimney, fireplace efficiency can be greatly improved through proper air control that the *Standards* require in the form of specific air control measures. Reduced infiltration is also a benefit when the fireplace is not operating (the majority of the time for most houses).

Installation of factory-built or masonry fireplaces (see Figure 2-11) must include:

- Doors covering the entire opening of the firebox that can be closed when the fire is burning.
- A combustion air intake that is at least 6 square inches equipped with a readily accessible, operable and tight-fitting damper.
- A flue damper with a readily accessible control.

These requirements do not apply to decorative gas appliances. Continuous burning pilot lights and the use of indoor air for cooling a firebox jacket, when that indoor air is vented to the outside of the building, are prohibited

Note: When a gas log, log lighter, or decorative gas appliance is installed in a fireplace; the flue damper shall be blocked open if required by manufacturer's installation instructions or the California Mechanical Code.

Fireplace requirements:

- closable metal or glass doors;
- combustion air intake (six square inch) for all fireplaces over a raised floor;
- combustion air intake (six square inch) for all fireplaces on exterior walls of slab on grade floors (see the CMC requirements related to outside combustion air);
- readily accessible flue damper control;
- no continuously burning pilot light; and
- no use of indoor air to cool firebox jacket.

Note: When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.

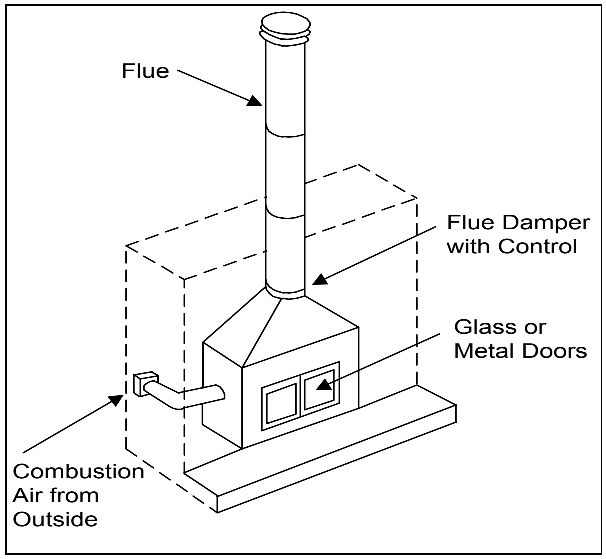
Free Standing Decorative gas appliance requirements:

- no continuously burning pilot light; and
- no use of indoor air to cool firebox jacket

Gas log requirement:

- no continuously burning pilot light.

Figure 2-11 – Fireplace Installation



Example 2-4 – Decorative Gas Appliances

Question

Are closable glass or metal doors required for decorative gas appliances?

Answer

No. The only requirement of *Standards* §150(e) that applies to decorative gas appliances is the prohibition on continuously burning pilot lights (§150(e)2). If there is a question about whether a device is a fireplace, which requires glass doors, the distinction is that a fireplace has a hearth, chamber or other place in which a solid fuel fire or a decorative gas log set may be burned, while a decorative gas appliance is for visual effect only and merely simulates a fire in a fireplace (§101.)

Question

If I want to have a gas log or some other device in the fireplace of my home, can I block open the damper? Can it have a standing pilot light?

Answer

§150(e)1 (which contains the requirements for fireplaces, decorative gas appliances, and gas logs), allows the flue damper to be blocked open if required by either the manufacturer's installation instructions or the California Mechanical Code. Continuously burning pilot lights in these appliances are prohibited by §150(e)2.

Question

§150(e)2 of the *Standards* states that no fireplace, decorative gas appliance or gas log can be installed if it has a continuously burning pilot light. The California Mechanical Code requires all gas appliances installed in California to have a manually operated shut-off valve, accessible to the inhabited space. Does this shut-off valve meet the intent of this section?

Answer

Not if the pilot light must be manually extinguished when the appliance is off. A unit that meets the intent of this section will have a pilot light that cannot stay on when the unit is off.

Question

A building plan specifies a freestanding gas heater that is very decorative, however, the equipment is vented and is rated as a room heater. Is it acceptable that this appliance have a pilot light.

Answer

Yes. Since this equipment is rated as a room heater, it can have a continuous burning pilot light.

Question

Do decorative gas appliances need glass or metal doors?

Answer

As defined in §101 of the *Standards*, decorative gas appliances do not need doors. The door requirement applies to masonry or factory-built fireplaces only (§150(e)1). If a decorative gas appliance is installed inside a fireplace, the fireplace needs doors. Consult with the manufacturer of the decorative gas appliance regarding combustion air requirements.

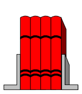
2.5 Space Conditioning

The design and installation of a building's space conditioning system has a significant impact on energy consumption and peak demand. As result, the *Standards* set a number of mandatory requirements related to space conditioning systems, including:

- Systems and Equipment Certification, Appliance Efficiency Regulations
- Space Conditioning Sizing
- Setback Thermostats
- Heat Pump Controls
- Insulation for Refrigerant Lines in Split System
- Ducts, Plenums, and Fans
- Duct Installation Standards
- Pilot Lights

The following sections discuss each of the relevant mandatory measures in detail.

2.5.1 Systems and Equipment Certification, Appliance Efficiency Regulations



§110

Section 110: Systems and Equipment – General.

Sections 111 through 119 establish requirements for the manufacture, construction, and installation of certain systems, equipment, and building components that are installed in buildings regulated by Title 24, Part 6. Systems, equipment, and building components listed below may be installed only if:

(a) The manufacturer has certified that the system, equipment, or building component complies with the applicable manufacture provisions of Sections 111 through 119; and

(b) The system, equipment, or building component complies with the applicable installation provisions of Sections 111 through 119.

No system, equipment, or building component covered by the provisions of Section 111 through Section 119 that is not certified or that fails to comply with the applicable installation requirements may be installed in a building regulated by Title 24, Part 6.

The systems, equipment, and building components covered are:

Appliances regulated by the Appliance Efficiency Regulations (Section 111)

Other space conditioning equipment (Section 112)

Other service water heating systems and equipment (Section 113)

Pool and spa heating systems and equipment (Section 114)

Gas appliances (Section 115)

Doors, windows, and fenestration products (Section 116)

Joints and other openings (Section 117)

Insulation and Cool Roofs (Section 118)

Lighting control devices (Section 119)

Section 111: Mandatory Requirements for Appliances Regulated by the Appliance Efficiency Regulations.

§111

Any appliance for which there is a California standard established in the Appliance Efficiency Regulations may be installed only if the manufacturer has certified to the Commission, as specified in those regulations, that the appliance complies with the applicable standard for that appliance. See Appendix 1-A for availability of directories of certified appliances.

Only HVAC equipment certified by manufacturers as complying with applicable *Appliance Efficiency Regulations* at the time of manufacture may be installed. Regulated equipment may not be sold in California unless it is certified. This includes the following HVAC equipment types:

- Room air conditioners
- Room air conditioning heat pumps
- Central air conditioners with a cooling capacity of less than 135,000 Btu/hr
- Central air conditioning heat pumps
- Gas-fired central furnaces
- Gas-fired boilers
- Gas-fired furnaces
- Gas-fired floor furnaces
- Gas-fired room heaters
- Gas-fired duct furnaces
- Gas-fired unit heaters

A summary of appliance efficiency regulations for gas-fired space heaters, air conditioners and heat pumps is given under the definition of the efficiency descriptors in Appendix G, *Glossary*, under *AFUE, SEER* and *HSPF.*

The *Standards* do *not* require certification for:

- Infrared heaters
- Nonstorage-type electric water heaters

- Electric resistance heaters
- Oil-fired furnaces (some are voluntarily listed with certified gas-fired furnaces)

Federal appliance efficiency standards require that:

1. Gas fan type central furnaces with an input rate less than 225,000 Btu/hr and manufactured on or after January 1, 1992, must be certified by the manufacturer to have an Annual Fuel Utilization Efficiency (AFUE) of 78% or greater.
2. Boilers with an input rate less than 300,000 Btu/hr and manufactured on or after January 1, 1992, must be certified by the manufacturer to have an AFUE of 75% or greater for gas steam type boilers and 80% or greater for all other boilers.
3. Split system air source air conditioners or heat pumps with an output rate less than 65,000 Btu/hr and manufactured on or after January 1, 1992, must be certified by the manufacturer to have a Seasonal Energy Efficiency Ratio (SEER) of 10.0 or greater.
4. Single packaged air source air conditioners or heat pumps with an output rate less than 65,000 Btu/hr and manufactured on or after January 1, 1993, must be certified by the manufacturer to have an SEER of 9.7 or greater.

California efficiency requirements for larger capacity equipment than covered above are specified in §112 of the *Standards.*

If any equipment does not meet the federal appliance efficiency standards, it may not be sold in California. Any equipment covered by the *Appliance Efficiency Regulations* and sold in California must have the date of manufacture permanently displayed in an accessible place on that equipment. This date is frequently included as part of the serial number.

Note: Equipment manufactured before the effective date of a new standard may be sold and installed in California indefinitely, as long as a performance approach demonstrates compliance of the building using the lower efficiency appliances.

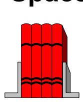
The person who signs off on the Installation Certificate (CF-6R) is required to certify that the actual equipment installed meets or exceeds the requirements of the *Appliance Efficiency Regulations* and that the equipment is equivalent to, or more efficient than the equipment described on the Certificate of Compliance attached to the plans.

Heating and Air-conditioning Systems

Verify that the make and model number of the installed unit matches that listed on the Installation Certificate (CF-6R). For furnaces, the make and model number can be verified by removing the front plate and checking the nameplate data. For cooling units, the nameplate data is typically located on the unit's case (cowling).

The person who signs off on the Installation Certificate (CF-6R) is certifying that the actual equipment installed meets or exceeds the requirements of the *Appliance Efficiency Regulations* and that it is equivalent to, or more efficient than, the equipment described on the Certificate of Compliance attached to the plans. Compare the CF-6R data to the CF-1R data shown on the plans.

2.5.2 Space Conditioning Sizing



§150(h)

(h) Space Conditioning Sizing

1. *Building design heat loss rate and design heat gain rate, shall be determined using a method based on any one of the following:*

A. *The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Handbook and Product Directory, Equipment Volume (1996), HVAC Applications Volume (1995), and Fundamentals Volume (1993), or*

B. *The Sheet Metal Air Conditioning Contractors National Association (SMACNA) Installation Standards for Residential Heating and Air Conditioning Systems, or*

C. *The Air Conditioning Contractors Of America (ACCA) Manual J.*

The design heat loss rate and design heat gain rate are two of the criteria that shall be used for equipment sizing and selection.

NOTE to Section 150(h)1.: Heating Systems must meet the minimum heating capacity required by UBC Section 310.11. The furnace output capacity and other specifications are published in the Commission's directory of certified equipment or other directories approved by the Commission.

2. *Design Conditions.*

For the purpose of sizing the space conditioning (HVAC) system, the indoor design temperatures shall be 70 degrees Fahrenheit for heating and 78 degrees for cooling. The outdoor design temperatures for heating shall be no lower than the Winter Median of Extremes column. The outdoor design temperatures for cooling shall be from the 0.5 percent Summer Design Dry Bulb and the 0.5 percent Wet Bulb columns for cooling, based on percent-of-year in ASHRAE publication SPCDX: Climate Data for Region X, Arizona, California, Hawaii, and Nevada, 1982, incorporated herein by reference.

The sizing of residential heating systems is regulated by the *Uniform Building Code (UBC)* and the *Standards*. The UBC requires that the heating system be capable of maintaining a temperature of 70 ºF at a distance three feet above the floor throughout the conditioned space of the building.

Indoor Design Temperatures for sizing calculations are 70 ºF for heating and 78 ºF for cooling.

Design conditions for 641 California locations, from the ASHRAE publication *Climatic Data For Region X: Arizona, California, Hawaii, Nevada by ASHRAE* (Fifth Edition, May 1982, supplement November 1994), are contained in Appendix C. If the actual city location for a project is not included in the ASHRAE listing, or if the data given for a particular city does not match the conditions at the actual site as well as that given for another nearby city, consult the local building department for guidance.

The load calculations must be submitted with compliance documentation when requested by the building department.

The mechanical contractor, who installs the equipment, completes and signs the Installation Certificate (CF-6R) and is ultimately responsible for proper sizing and equipment selection.

The calculated heat gain and heat loss rates (load calculations) are just two of the criteria for sizing and selecting equipment. The load calculations may be prepared by: (1) the documentation author and submitted to the mechanical contractor for signature, (2) a mechanical engineer, or (3) the mechanical contractor who is installing the equipment.

The load calculations do not need to be submitted with compliance documentation unless requested by the building department.

2.5.3 Setback Thermostats

§150(i)

(i) ***Setback Thermostats.*** *All heating and/or cooling systems other than wood stoves shall have an automatic thermostat with a clock mechanism or other setback mechanism approved by the Executive Director that shuts the system off during periods of non-use and that allows the building occupant to automatically set back the thermostat set points for at least 2 periods within 24 hours.*

EXCEPTION to Section 150(i): Gravity gas wall heaters, gravity floor heaters, gravity room heaters, non-central electric heaters, room air conditioners, and room air conditioner heat pumps need not comply with this requirement.

Additionally, room air conditioner heat pumps need not comply with Section 112(b). The resulting increase in energy use due to elimination of the setback thermostat shall be factored into the compliance analysis in accordance with a method prescribed by the Executive Director.

All heating and/or cooling systems must have an automatic setback thermostat with a clock mechanism that shuts the system off during periods of non-use and that allows the building occupant to automatically set back the thermostat set points for at least two periods within 24 hours.

An exception applies only for computer performance compliance when a "non-setback" control is modeled for the listed non-central space-conditioning systems.

If more than one piece of heating equipment is installed in a residence or dwelling unit, the set-back requirement may be met either by controlling all heating units by one setback thermostat or by controlling each unit with a separate setback thermostat. Separate heating equipment units may be provided with a separate on/off control capable of overriding the setback thermostat if desired.

Unless the elimination of the setback thermostat is factored into the compliance analysis for the following systems, the setback thermostat must be installed *(compliance with a prescriptive package always requires a setback thermostat):*

- Non-central electric heaters
- Room air conditioners
- Room air conditioner heat pumps
- Gravity gas wall heaters
- Gravity floor heaters
- Gravity room heaters
- Room air conditioners

Automatic setback thermostats can add both comfort and convenience to a home. Occupants can wake up to a warm house in the winter and come home to a cool house in the summer without using unnecessary energy.

All heating and/or cooling systems must have an automatic setback thermostat with a clock mechanism that shuts the system off during periods of non-use and that allows the building occupant to automatically set back the thermostat set points for at least two periods within 24 hours. Note that setback thermostats for heat pumps must be "smart thermostats" that minimize the use of supplementary electric resistance heating during startup and recovery from setback, as discussed in the next section

The only exception is if the HVAC system on the CF-1R shows the thermostat type as "non-setback" for a building using computer performance compliance. This exception is not allowed for the alternative component packages because this approach does not factor into the compliance the lack of setback capabilities. The exception also only applies to non-central systems as identified above.

Check the CF-1R for automatic setback thermostat requirements. A setback thermostat is mandatory for central systems. An exception is allowed if : (1) the building complied using a computer performance approach with a non-setback thermostat; and (2) the system is one of the following non-central types:

- Non-central electric heaters
- Room air conditioners
- Room air conditioner heat pumps
- Gravity gas wall heaters
- Gravity floor heaters
- Gravity room heaters
- Room air conditioners

This exception is not allowed for alternative component packages because this approach does not factor into the compliance the lack of setback capabilities. Setback is typically achieved with a timeclock on the thermostat or with a digital readout.

Example 2-5 – Setback Thermostat Requirement

Question

Am I exempt from the requirement for a setback thermostat if I have a gravity wall heater or any of the equipment types listed in the exception to §150(i)?

Answer

Exemption from the requirement depends on the compliance approach you are using. The exception requires that “the resulting increase in energy use due to the elimination of the setback thermostat shall be factored into the compliance analysis.” The only compliance approach that models this condition is the computer performance compliance approach. To be exempt from the setback thermostat requirement, the building/space must be modeled with “non-setback.” Any time the alternative component packages are used for compliance, a setback thermostat is required, regardless of the type of heating/cooling system (except wood stoves).

2.5.4 Heat Pump Controls

§112(b)

(b) ***Controls for Heat Pumps with Supplementary Electric Resistance Heaters****. Heat pumps with supplementary electric resistance heaters shall have controls:*

1. *That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and*
2. *In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.*

EXCEPTION to Section 112(b): The controls may allow supplementary heater operation during:

I. Defrost; and

II. Transient periods such as start-ups and following room thermostat setpoint advance, if the controls provide preferential rate control, intelligent recovery, *staging, ramping, or another control mechanism designed to preclude the unnecessary operation of supplementary heating.*

Any heat pump with supplementary electric resistance heating must have controls that have two capabilities to limit the electric resistance heating. The first capability of the control is to set the cut-on and cut-off temperatures for compression and supplementary heating at different levels. For example, if the heat pump begins heating when the inside temperature reaches 68 ºF, the electric resistance heating is set to come on if the temperature gets below 65 ºF; and the opposite off mode so that if the heat pump shuts off when the temperature reaches 72 ºF, the back-up heating shuts off at 68ºF.

The second function of the control prevents the supplementary electric resistance heater from operating when the heat pump alone can meet the heating load, except during defrost. There is a limited exception to this second function for “smart thermostats” that provide: intelligent recovery, staging, ramping, or another control mechanism that prevents the unnecessary operation of supplementary electric resistance heating when the heat pump alone can meet the heating load. To meet the setback thermostat requirements discussed in the previous section, a setback thermostat for a heat pump must be a “smart thermostat” that minimizes the use of supplementary heating during startup and recovery from setbacks

With such controls supplementary heater operation is permitted during defrost and transient periods such as start-ups, and following room thermo-stat setpoint advance.

Note: Room air conditioner heat pumps are not required to comply with these requirements.

2.5.5 Insulation for Refrigerant Lines in Split System Air Conditioners

Two refrigerant lines connect the indoor and outdoor units of split system air conditioners and heat pumps: the liquid line and the suction line. The liquid line is at an elevated temperature and it is helpful if heat escapes, therefore, it should generally not be insulated. However, the suction carries refrigerant from the indoor unit back to the outdoor unit and is at a temperature below 55 ºF. The suction line must be insulated with at least R-3 insulation, per the requirements of §150 (j) 2.

Insulation used with the suction line must be protected from physical damage or from UV deterioration. Pipe insulation in outdoor locations is typically protected by aluminum or sheet metal jacket, painted canvas, a plastic cover, or coatings that are water retardant and UV resistant. See §150 (m) 9.

2.5.6 Ducts, Plenums, and Fans

The section focuses on minimum mandatory requirements for duct construction and includes excerpts from the *California Mechanical Code* and construction details from the Air Diffusion Council. Chapter 4 and Appendices J and K contain additional details on construction and diagnostic testing of ducts to eliminate potentially significant energy losses.

A. Standards Language

§150(m)

The following language (in italics) is taken from §150 (m) of the *Standards*.

1. *CMC Compliance. All air distribution system ducts and plenums, including but not limited to mechanical closets, and air handler boxes shall be installed, sealed and insulated to meet the requirement of the 1998 CMC Sections 601, 603, 604 and*

Standard 6-3, incorporated herein by reference. Portions conveying conditioned air shall either be insulated to a minimum installed level of R-4.2 (or any higher level required by CMC Section 604) or be enclosed entirely in conditioned space. Connections of metal ducts and the inner core of flexible ducts shall be mechanically fastened. Openings shall be sealed with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A or UL 181B. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.

Building cavities, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross sectional area of the ducts.

2. *Factory-Fabricated Duct Systems.*

   A. *All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections and splices.*

   B. *All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts shall comply with UL 181.*

   C. *All pressure-sensitive tapes, mastics used with flexible ducts shall comply with UL 181 or UL 181B.*

   D. *Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.*

3. *Field-Fabricated Duct Systems.*

   A. *Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems shall comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants or other closure systems used for installing field-fabricated duct systems shall meet the applicable requirements of UL 181, UL 181A or UL 181B. Note: If these requirements do not apply then they are met.*

   B. *Mastic Sealants and Mesh.*

      i. *Sealants shall comply with UL 181, UL 181A, or UL 181B, and be non-toxic and water resistant.*

      ii. *Sealants for interior applications shall pass ASTM tests C 731 (extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.*

      iii. *Sealants for exterior applications shall pass ASTM tests C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.*

      iv. *Sealants and meshes shall be rated for exterior use.*

   C. *Pressure-Sensitive Tape. Pressure-sensitive tapes shall comply with UL 181, UL 181A, or UL 181B.*

   D. *Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.*

   E. *Drawbands Used with Flexible Duct.*

      i. *Drawbands shall be either stainless-steel worm-drive hose clamps or uv-resistant nylon duct ties.*

ii. Drawbands shall have a minimum tensile strength rating of 150 pounds.

iii. Drawbands shall be tightened as recommended by the manufacturer with an adjustable tensioning tool.

F. Aerosol-Sealant Closures.

i. Aerosol sealants shall meet the applicable requirements of UL 181, 181A or 181B and be applied according to manufacturer specifications. If the requirements of UL181, UL181A, or UL181B do not apply then these requirements are met.

ii. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

4. All duct insulation product R-values shall be based on insulation only (excluding air films, vapor barriers, or other duct components) and tested C-values at 75°F mean temperature at the installed thickness, in accordance with ASTM C518-85 or ASTM C177-85, incorporated herein by reference, and certified pursuant to Section 118.

5. The installed thickness of duct insulation used to determine its R-value shall be determined as follows:

A. For duct board, duct liner and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness shall be used.

B. For duct wrap, installed thickness shall be assumed to be 75 percent (25 percent compression) of nominal thickness.

C. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by 2.

6. Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of 3 feet, showing the thermal performance R-value for the duct insulation itself (excluding air films, vapor barriers, or other duct components), based on the tests in Section 150(m)4. and the installed thickness determined by Section 150(m)5.C.

7. All fan systems, regardless of volumetric capacity, that exhaust air from the building to the outside shall be provided with backdraft or automatic dampers to prevent air leakage.

8. All gravity ventilating systems that serve conditioned space shall be provided with either automatic or readily accessible, manually operated dampers in all openings to the outside except combustion inlet and outlet air openings and elevator shaft vents.

9. Protection of Insulation. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind but not limited to the following: Insulation exposed to weather shall be suitable for outdoor service; e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

EXCEPTION to Section 150(m)1.: The requirements do not apply to ducts and fans integral to a wood heater or fireplace.

Summary of Requirements from Standards

Insulation and Installation

Each duct system efficiency measure must meet or exceed both the Energy Efficiency Standards and the CMC. Where there are differences between the two standards, the more stringent applies. Ducts conveying conditioned air must either be insulated to a minimum installed level of R-4.2 (or any higher level required by the CMC Section 604) or be enclosed entirely in conditioned space. All duct insulation R-values shall be based on insulation only (excluding air films, vapor barriers or other duct components) and tested C-factors as specified above in §150(m) 4, and certified pursuant to §118. The installed thickness of duct insulation used to determine its R-value shall be determined in accordance with §150 (m) 5. On and after the effective date designated by the California Building Standards Commission for the 2000 CMC, duct installation, sealing and insulation shall comply with Sections 601, 602, 604, 605 and Standard 6-5 of the 2000 CMC.

In two situations, Section 604 of the CMC requires R-6.3 duct insulation instead of R-4.2. These are:

1. When cooling system ducts are installed on the roof or exterior of the building.
2. When heating system ducts are installed on the roof (exterior) of the building in an area with greater than 8,000 heating degree days (see Appendix C heating degree days (HDD)).

Ducts in Concrete Slab

Ducts located in a concrete slab must also meet the R-4.2 insulation requirements, but for these ducts, there are other issues as well. If ducts are located in the soil beneath the slab or embedded in the slab, the insulation material should be designed and rated for such installation. Insulation installed in below grade applications should resist moisture penetration, e.g. closed cell foam such as extruded polystyrene. Common pre-manufactured duct systems are not suitable for below grade installations. If concrete is to be poured directly over the ducts, then the duct construction and insulation system should be sturdy enough to resist the pressure and not collapse. Insulation should be of a type that will not compress or it should be located inside a rigid duct enclosure. The only time that common flex ducts are suitable in a below grade application is when a channel is provided in the slab.

Notes:

- The insulation levels of the CMC are mandatory *minimum* levels. If compliance calculations show a higher R-value is being used for credit, the higher value is required.
- The duct location must match the location shown on the Certificate of Compliance (CF-1R).

Duct Requirements

These requirements are from both the *Standards* and the CMC.

Additional Duct Construction Requirements

1. Mechanical fastening of connections of metal ducts and the inner core of flexible ducts is required.
2. Openings must be sealed with mastic, tape, aerosol sealant or other duct closure systems that meet the applicable requirements of UL 181.
3. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.
4. 4. Building spaces such as cavities between walls, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air including return air and supply air. The practice of using drywall materials as the interior surface of a return plenum is not allowed. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross sectional area of the ducts. Although a HERS rater may examine this as a part of their responsibilities when they are involved in a project, the enforcement of these minimum standards for ducts is the responsibility of the building official.

Ducts and fans integral to a wood heater or fireplace are exempt from these insulation and installation requirements.

Factory-Fabricated Duct Systems and Field-Fabricated Duct Systems

Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands. The enforcement of these minimum standards is the responsibility of the building official.

Product Markings

Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of three feet, showing the R-value for the duct insulation (excluding air films, vapor barriers or other duct components), based on the tests and thickness specified in §150(m) above.

Fan, Exhaust, and Ventilation

Fan systems that exhaust air from the building to the outside must be provided with back draft or automatic dampers.

Gravity ventilating systems must have an automatic or readily accessible, manually operated damper in all openings to the outside, except combustion inlet and outlet air openings and elevator shaft vents. This includes clothes dryer exhaust when installed in conditioned space.

Protection of Insulation

Insulation shall be protected from damage as described in §150 (m) 9.

Installation

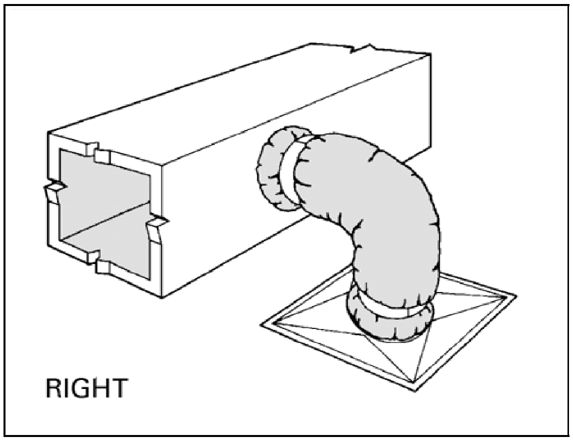
Appendix K also contains a recommended detailed listing for inspecting quality constructed ducts and Section 6.310 of Standard 6-3 of the CMC has an enforcement checklist for flexible duct installations.

2.5.7 Duct Installation Standards

These following standards are derived from the CMC (Section 6-30 are based on the descriptions given in *Flexible Duct Performance and Installation Standards* published by the Air Diffusion Council, 104 South Michigan Avenue, Suite 1500, Chicago, Illinois 60603, telephone (312) 201-0101. They have been modified to be consistent with the requirements of the Energy Efficiency Standards.

Note: These are minimum standards. Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands. Building cavities, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air including return air and supply air. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross sectional area of the ducts. The enforcement of these minimum standards is the responsibility of the building official.

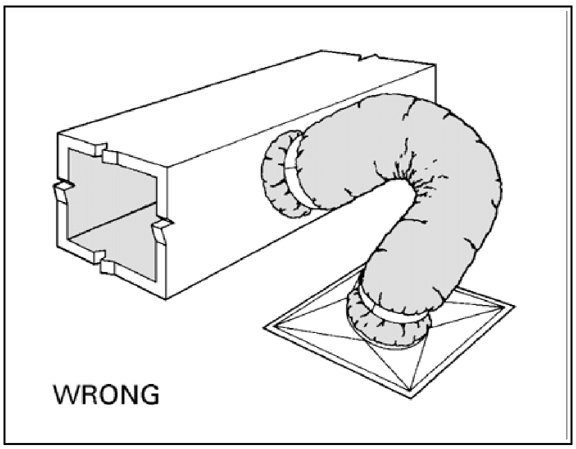
Figure 2-12 – Duct Installation (Right)



Ducts shall be installed fully extended as shown in Figure 2-12. If compressed or with excess lengths, as shown in

Figure 2-13, friction losses are increased.

Figure 2-13 – Duct Installation (Wrong)



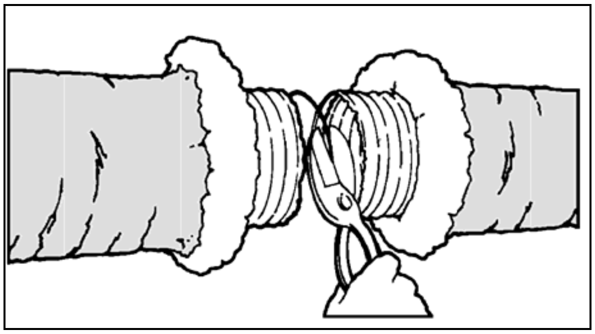
Avoid bending ducts across sharp corners or incidental contact with metal fixtures, pipes or conduits. Also avoid installing the duct near hot equipment such as furnaces, boilers, or steam pipes, which are above the recommended flexible duct use temperature.

Connecting, Joining and Splicing Flexible Duct

All connections, joints and splices shall be made in accordance with the manufacturer's installation instructions. For flexible ducts with plain ends, standardized installation instructions are shown in Figure 2-14A through C for nonmetallic ducts. Because of the variety of ducts and duct assemblies with special end treatments, no standardized installation instructions are shown. Instead, consult the manufacturer's installation instructions. Sheet metal collars to which the flexible ducts with plain ends are attached shall be a minimum of 2 inches in length. Sheet metal sleeves used for joining two sections of flexible ducts with plain ends shall be a minimum of 4 inches in length. Sheet metal collars and sleeves should be beaded for pressures exceeding 2 inches w.g. (500 Pa) and for diameters 12 inches and larger when used with metallic ducts.

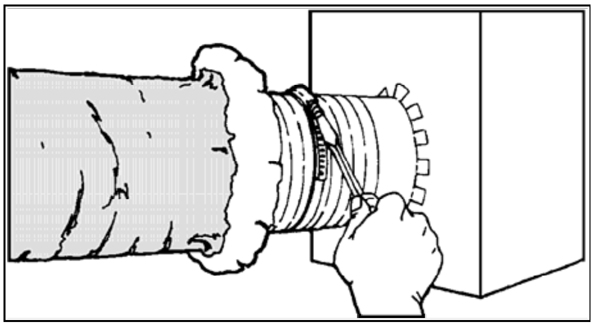
Nonmetallic Air Ducts and Air Connectors

Figure 2-14 A – Connections for Nonmetallic Air Ducts and Air Connectors



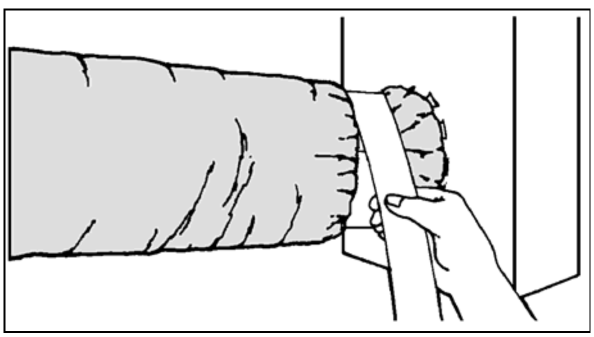
Cut completely around and through duct with knife or scissors. Cut wire with wire cutters.

Figure 2-14 B – Connections for Nonmetallic Air Ducts and Air Connectors



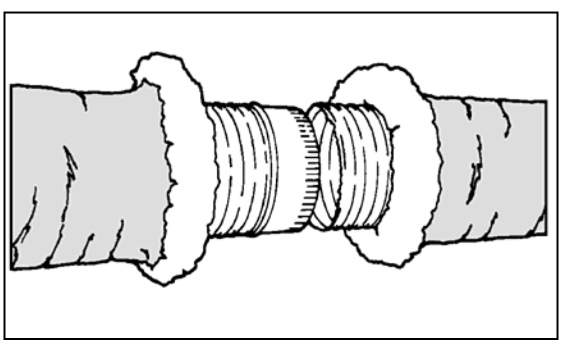
Pull jacket and insulation back from core. Slide at least 1 inch of core over collar, pipe or fitting. Tape core with at least two wraps of tape. Secure with a clamp. Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands. The connector fitting to the plenum shown as a "finger joint" connection in this figure is shown prior to sealing. Mastic should be used for sealing this connection to the plenum.

Figure 2-14 C – Connections for Nonmetallic Air Ducts and Air Connectors



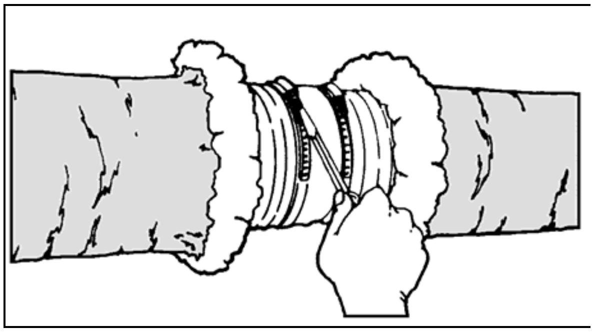
Pull jacket and insulation back over core. Tape jacket with at least two wraps of duct tape. Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands. A clamp must be used in place of or in combination with cloth back rubber adhesive duct tape.

Figure 2-15 A – Splices for Nonmetallic Air Ducts and Air Connectors



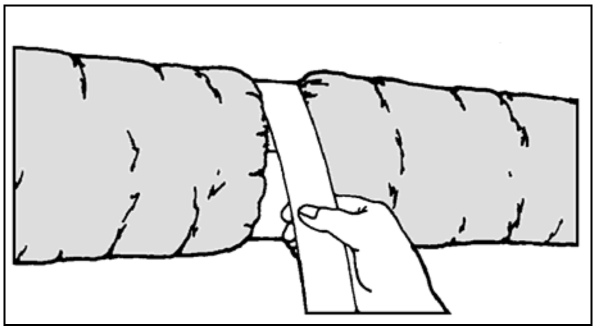
Peel back jacket and insulation from core. Butt two cores together on a standard 4-inch metal sleeve.

Figure 2-15 B – Splices for Nonmetallic Air Ducts and Air Connectors



Tape core with at least two wraps of approved tape. Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands. Secure with two clamps.

Figure 2-15 C – Splices for Nonmetallic Air Ducts and Air Connectors



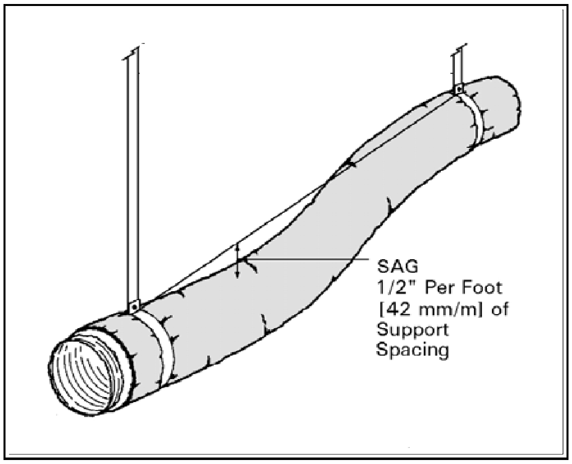
Pull jacket and insulation back over cores. Tape jacket. Tape jacket with at least two wraps of approved tape. Duct systems may not use cloth back, rubber adhesive duct tape unless it is installed in combination with mastic and drawbands.

Notes (for Figures Figure 2-14 and Figure 2-15):

1. Use beaded fittings for pressures exceeding 2 inches w.g. (500 Pa) and for diameters 12 inches and larger.
2. Use tapes listed and labeled to Standard UL 181B and marked 181B-FX.
3. Use clamps as specified on manufacturer's UL 181 installation instructions.

Supporting Flexible Duct

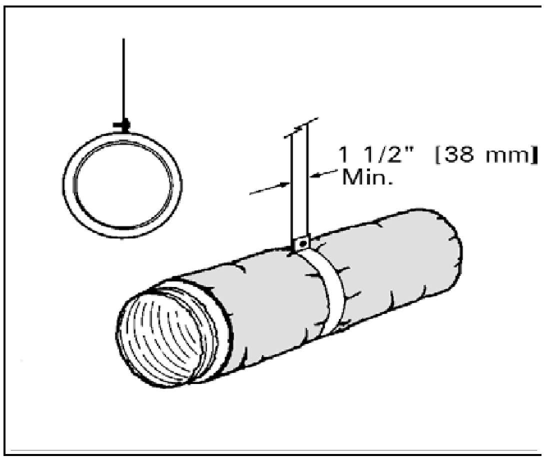
Figure 2-16 – Flexible Duct Support



Flexible duct shall be supported at manufacturers recommended intervals, but no greater than a distance of four feet. Maximum permissible sag is 1/2 inch per foot of space between supports.

A connection to rigid duct or equipment shall be considered a support joint. Long horizontal duct runs with sharp bends shall have additional supports before and after the bend approximately one duct diameter from the centerline of the bend.

Figure 2-17 – Hanger or Saddle Material



Hanger or saddle material in contact with the flexible duct shall be of sufficient width to prevent any restriction of the internal diameter of the duct when the weight of the supported section rests on the hanger or saddle material. In no case will the material in contact with the flexible duct be less than 1-1/2 inches wide.

2.5.8 Pilot Lights

Continuously burning pilot lights are prohibited for fan type central furnaces. For more information see Section 2.6.6.

2.6 Water Heating and Plumbing

This section discusses the mandatory measures for the following topics.

Equipment Certification

Water Heater Tank Insulation

Pipe Insulation

Solar Water Heating

Pool and Spa Equipment

Pilot Lights Prohibited

2.6.1 Equipment Certification

Hot water heaters must be certified by manufacturers as complying with applicable *Appliance Efficiency Regulations* at the time of manufacture. Regulated equipment may not be sold in California unless it is certified. This includes the following types of water heaters and appliances:

- Gas water heaters
- Heat pump water heaters
- Electric storage water heaters
- Oil-fired water heaters
- Shower heads and faucets

These appliances are regulated either by the Appliance Efficiency Regulations or by section 113.

If any equipment does not meet the federal appliance efficiency standards, it may not be sold in California. Any equipment covered by the *Appliance Efficiency Regulations* and sold in California must have the date of manufacture permanently displayed in an accessible place on that equipment. This date is frequently included as part of the serial number.

The person who signs off on the Installation Certificate (CF-6R) is required to certify that the actual equipment installed meets or exceeds the requirements of the *Appliance Efficiency Regulations* and that the equipment is equivalent to, or more efficient than the equipment described on the Certificate of Compliance attached to the plans.

Water Heating

The number and types of water-heater systems installed must correspond to the approved CF-1R. The location of the water heater, adding a recirculating system, and a hot water-recovery system are all factors of the distribution system and play a significant role in water heating compliance. The distribution system must correspond to plan specifications.

The installation criteria for water heating distribution systems are described in Chapter 6, Section 6.6.

Faucets and Shower Heads

Faucets and showerheads are limited by a federal standard to 2.5 gallons per minute. If equipped with a flow restrictor, it must be mechanically retained which means it requires eight pounds or more of pulling force to remove.

Note: A reduced flow rate saves in two ways: (1) water-heating energy makes up about one-quarter of all energy in residences, so less water means less hot water; and (2) a 10 % cut in water use means $100,000 in electricity savings from reduced pumping costs theoretically for one water district.

Water Heating

Check that the number and types of water-heater systems are installed, as indicated on the CF-6R, and check to see that this corresponds to the approved CF-1R. The distribution system is also significant and must correspond to plan specifications. For example:

- If the plans indicate the presence of a hot water recovery system, it must be installed.

- If a recirculation system is installed, verify that it was accounted for in the compliance documentation (CF-1R) and check for any required controls (e.g., demand pump, timer).
- If a point of use credit is specified, the water heater must be no further than eight feet from all hot water outlets (excluding washing machines).

See Section 5.1, for a summary of the different distribution system types and installation requirements for each. Note whether each one is a credit or a penalty as compared with the standard distribution system.

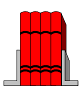
Verify that the make and model number of the installed water-heater unit match those listed on the Installation Certificate (CF-6R).

If a storage gas water heater has an energy factor (EF) of less than 0.58, an R-12 water-heater blanket is required (internal insulation cannot be used to satisfy this mandatory requirement). For water heaters with 0.58 EF or higher or large storage (typically commercial size) water heaters whose rated input is greater than 75,000 Btu/h, that are not rated using an energy factor, no insulation blanket is required. The blanket should be securely attached around the water heater. The top of the water heater should not be insulated and a cutout in the blanket should be provided for combustion air intake.

Faucets and Shower Heads

Faucets and showerheads are limited by a federal standard to 2.5 gallons-per-minute. If equipped with a flow restrictor, it must be mechanically retained which means it requires eight pounds or more of pulling force to remove.

2.6.2 Water Heater Tank Insulation



§150(j)1

A. Storage gas water heaters with an energy factor < 0.58 shall be externally wrapped with insulation having an installed thermal resistance of R-12 or greater.

B. Unfired hot water tanks, such as storage tanks and backup storage tanks for solar water heating systems, shall be externally wrapped with insulation having an installed thermal resistance of R-12 or greater or have internal insulation of at least R-16 and a label on the exterior of the tank showing the insulation R-value.

Insulation is not a factor in the compliance calculations, but is a mandatory requirement for some units. For storage water heaters with an energy factor of less than 0.58, an R-12 insulation wrap is required. Any unfired tanks (used as a back-up for solar water heating or as storage for a boiler) must either be insulated externally with R-12 or have a label indicating the tank is internally insulated with R-16.

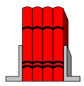
Storage water heaters with an efficiency of less than 0.58 energy factor must be wrapped with an R-12 insulation blanket. Internal insulation cannot be substituted for this insulation. Large storage water heaters with a rated input greater than 75,000 Btu/h that are not rated with an energy factor (EF) are not required to have an external R-12 insulation blanket.

Unfired tanks used as a back-up for solar water heating, or as storage for a boiler, must either be insulated externally with R-12 or have a label indicating that the tank is internally insulated with R-16. Alternatively, proof that the heat loss of the tank surface, based on an 80ºF water-air temperature difference, is less than 6.5 Btu/hr-ft^2.

In most common situations a water heater blanket is not required. There are only two cases where an R-12 wrap is required:

- *Storage* water heater with an energy factor of less than 0.58.
- *Unfired* water heater without a label specifying R-16 internal insulation.

2.6.3 Pipe Insulation



§150(j)2

Piping, whether buried or unburied, for recirculating sections of domestic hot water systems, piping from the heating source to the storage tank for an indirect-fired domestic water heating system, cooling system piping below 55 degrees Fahrenheit, and the first five feet of hot and cold water pipes from the storage tank for non-recirculating systems shall be thermally insulated in accordance with Table No. 1-T [Table 2-6 below].

EXCEPTIONS to Section 150(j)2.: The following piping does not have to be thermally insulated: (1) factory-installed piping within space conditioning equipment; and (2) piping that conveys fluids that have a design operating temperature range between 55 degrees and 105 degrees Fahrenheit.

NOTE to Section 150(j)2.: Where the Executive Director approves a water heater calculation method for a particular water heating recirculation system, piping insulation requirements shall be those specified in the approved calculation method.

Table 2-6 – Pipe Insulation Requirements Minimum R-value – Table 1-T from §150(j)2.

	Pipe Diameter	
System	Less than or equal to 2"	Greater than 2"
Domestic Hot Water	R-4	R-6
Hydronic Heating Supply Lines	R-4	R-6
Cooling Systems (pipes below 55°F)	R-3	R-4

The suction line from the indoor unit to the outdoor unit in split system air conditioners and heat pumps must be insulated with a minimum of R-3 insulation, since this line carries a fluid at a temperature below 55 ºF.

The following piping must be insulated in accordance with Table 2-6 above:

- Storage tanks for a non-recirculating system must have pipe insulation on both hot and cold water pipes for a length of five feet. There is no exception for water heater piping in the conditioned space.
- Insulate the cold water pipe close to the storage tank since the cold water pipe draws heat from the tank and loses some of that heat convectively to the air.
- Recirculating sections of domestic hot water systems (the entire length of piping, whether buried or exposed).
- Indirect fired domestic hot water system piping from the heating source to the storage tank.
- Cooling system piping below 55 ºF.

Other installation information:

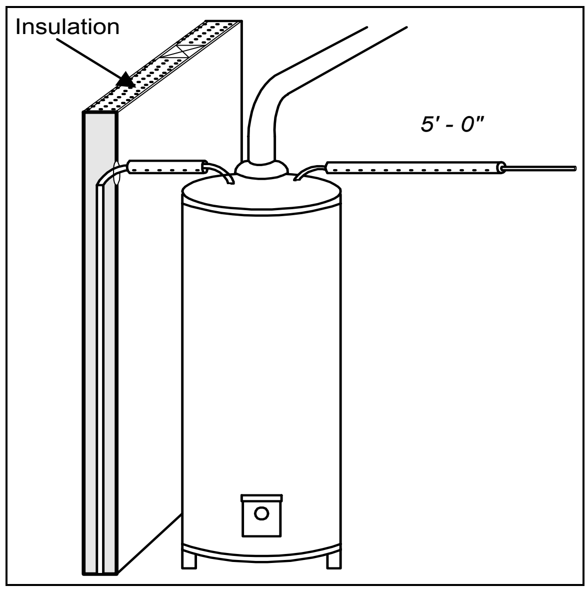
- No insulation should be installed closer than six inches from the flue. If possible bend the pipe away from the flue, otherwise, it may be necessary to stop pipe insulation short of the storage tank (see *1997 California Mechanical Code*, Section 304, Table 3-C).
- All pipe insulation seams should be sealed.

- Installed piping should not be located in supply or return air plenums.
- Hot and cold water piping, when installed in parallel runs should be a minimum of six inches apart.
- If the pipe is interrupted by a wall, the wall insulation can, if it surrounds the pipe as shown in Figure 2-18, be used to meet the mandatory requirements in place of pipe insulation. The full five feet must be insulated.
- If a firewall interrupts the first five feet of pipe, the insulation may be interrupted at the wall and continued on the other side.

Piping *exempt* from this insulation requirement includes:

- Factory installed piping within space conditioning equipment; and
- Piping that conveys fluids that have a design operating temperature range between 55ºF and 105ºF.

Figure 2-18 – Meeting Pipe Insulation Requirements for Storage Tank Water Heaters



The following insulation is required (insulation values are for two inches or less pipes):

- R-4 on the first five feet of hot and cold water pipes for storage, non-recirculating system. There is no exception for water heater piping in the conditioned space.
- R-4 on the entire length of hot water recirculating piping on a recirculating system, regardless of the location of the piping.
- R-4 on piping from the heating source to the storage tank for boilers or solar water heating;
- R-3 on cooling system piping below 55ºF; and,
- Other insulation shown on the CF-1R that is being used for a credit and must be installed as indicated on the plans.

Example 2-6 – Water Heater Pipe Insulation

Question

I thought I was supposed to insulate the water heater pipes for either the first five feet or the length of piping before coming to a wall, whichever is greater. Did I misunderstand?

Answer

Yes. The requirement is that you must insulate the entire length of the first five feet, regardless of whether there is a wall (*Standards*, §150(j)2). You have two options: (1) interrupt insulation for a fire wall and continue it on the other side of the wall, or (2) run the pipe through an insulated wall, making sure that the wall insulation completely surrounds the pipe.

Question

When insulating the water heater piping, do I need to put insulation on the first five feet of cold water pipe?

Answer

Yes. §150(j)2 requires insulation on the cold water pipe also. When heated, the water expands and pushes hot water out the cold water line. This can start thermosyphoning, which continues to remove heat from the stored water. The insulation helps reduce this effect.

Question

If the energy calculations show R-4 pipe insulation, is this a credit? What are the installation requirements for obtaining credit?

Answer

If R-4 pipe insulation is indicated on any form other than the MF-1R it is being used to obtain credit. (The MF-1R form indicates only mandatory insulation requirements—the first five feet of piping for a non-recirculating system or the entire length of recirculating sections of hot water piping for a circulating system.) If R-4 is indicated on the Computer Summary (C-2R) or the Certificate of Compliance (CF-1R) it is being calculated as a credit.

The installation requirements for receiving the R- 4 piping insulation credit are:

A non-recirculating water-heating system

R-4 (or greater) insulation

Insulation applied to all 3/4 inch or larger hot water mains

Neither attic, wall, nor underfloor insulation can be used as a substitute for this insulation.

These requirements are in addition to mandatory insulation requirements of §150(j).

Question

Can I get pipe insulation credit for a recirculating water-heating system?

Answer

No. Recirculating water-heating systems have a mandatory insulation requirement for the recirculating sections of hot water pipes. Pipes less than 2 inches must be insulated to R-4 and pipes greater than 2 inches need R-6 insulation.

Question

When I'm insulating the pipes for a recirculating water-heating system, I insulate the entire length of hot water pipes. Do I need to insulate the runouts?

Answer

No. Since the water in runouts does not recirculate, they do not need to be insulated.

2.6.4 Solar Water Heating

§150(j)3

Solar water heating systems and/or collectors shall be certified by the Solar Rating and Certification Corporation.

Solar water-heating systems and/or collectors must be certified by the Solar Rating and Certification Corporation (SRCC).

- Certification of solar system and/or collectors by the Solar Rating and Certification Corporation (SRCC)
- Piping insulation from the indirect fired hot water system to the heat source
- Tank insulation on an indirect fired water heater without a label specifying R-16 internal insulation.

2.6.5 Pool and Spa Equipment

§114

Mandatory Requirements for Pool and Spa Heating Systems and Equipment.

(a) Certification by Manufacturers. Any pool or spa heating system or equipment may be installed only if the manufacturer has certified that the system or equipment has all of the following:

1. Efficiency. A thermal efficiency for gas-fired systems of at least 78%, when tested according to ANSI Standard Z21.56-1994; and

2. On-Off Switch. A readily accessible on-off switch, mounted on the outside of the heater, that allows shutting off the heater without adjusting the thermostat setting; and

3. Instructions. A permanent, easily readable, and weatherproof plate or

card that gives instruction for the energy efficient operation of the pool or spa and for the proper care of pool or spa water when a cover is used; and

4. Electric Resistance Heating. No electric resistance heating; and

EXCEPTION No. 1 to Section 114(a)4.: Listed package units with fully insulated enclosures, and with tight-fitting covers that are insulated to at least R-6.

EXCEPTION No. 2 to Section 114(a)4.: Pools or spas deriving at least 60% of the annual heating energy from site solar energy or recovered energy.

5. Pilot Light. No pilot light.

(b) Installation. Any pool or spa heating system or equipment shall be installed with all of the following:

1. Piping. At least 36" of pipe between the filter and the heater, to allow for the future addition of solar heating equipment; and

2. Covers. A cover for outdoor pools or outdoor spas; and

EXCEPTION to Section 114(b)2.: Pools or spas deriving at least 60% of the annual heating energy from site solar energy or recovered energy.

3. Directional Inlets and Time Switches for Pools. If the system or equipment is for a pool:

A. The pool shall have directional inlets that adequately mix the pool water; and

B. The circulation pump shall have a time switch that allows the pump to be set to run in the off-peak electric demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

EXCEPTION to Section 114(b)3.B.: Where applicable public health standards require on-peak operation.

Before any pool or spa heating system or equipment may be installed, the manufacturer must certify to the Commission that the system or equipment complies with §114. The requirements include minimum heating efficiency, an on-off switch, permanent operating instructions, no pilot light, and no electric resistance heating. There are two exceptions for electric heaters- they may be installed for:

- Listed package units with fully insulated enclosures (e.g., hot tubs), and with tight-fitting covers, insulated to at least R-6.
- Pools or spas getting 60% or more of their annual heating from site solar energy or recovered energy.

Any pool or spa must be installed with all of the following:

- At least 36 inches of pipe between the filter and heater to allow for the future addition of solar heating equipment;
- A cover for outdoor pools or outdoor spas except for pools or spas deriving at least 60% of the annual heating energy from site solar energy or recovered energy;
- If the heating system or equipment is for a pool:
  a. The pool must have directional inlets to adequately mix the pool water; and
  b. The circulation pump must be capable of being set to run for the minimum number of hours to maintain the water in an acceptable condition and to run at off-peak electric demand periods.

Equipment

Gas:

1. Thermal efficiency 78%,
2. Accessible shut-off switch (independent of temperature),
3. Permanent and readable instructions for efficient operation and maintenance, and
4. No pilot light.

Electric:

1. NOT ALLOWED except when:
2. At least 60% solar heating or site recovered energy provided, and
3. Package unit has fully insulated enclosure with tight-fitting, R-6 cover (e.g., hot tub).

Installation

- At least 36-inch pipe length between filter/ heater (for future solar),
- Cover (except if solar heating),
- Ability to mix pool water, and
- Time switch for pool pump (allows control of length of time and time of day)

2.6.6 Pilot Lights Prohibited

This mandatory measure applies to HVAC equipment as well.

§115

Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited.

Any natural gas system or equipment listed below may be installed only if it does not have a continuously burning pilot light:

(a) Fan type central furnaces.

(b) Household cooking appliances.

EXCEPTION to Section 115(b): Household cooking appliances without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/hr.

(c) Pool heaters.

(d) Spa heaters.

Any of the following natural gas systems or equipment may be installed only if it does *not* have a continuously burning pilot light:

- Fan type central furnaces
- Household cooking appliances, except cook-ing appliances without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/hr
- Pool heaters
- Spa heaters
- Fireplace*
- Decorative gas appliance*
- Gas log*

*§150(e) specifies that a fireplace, decorative gas appliance, or gas log cannot have a continuously burning pilot light.

The following natural gas appliances cannot have a standing or continuously burning pilot light:

- Fan type central furnaces
- Household cooking appliances, except cook-ing appliances without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/hr
- Pool heaters
- Spa heaters
- Fireplace
- Decorative gas appliance
- Gas log

Example 2-7 – Continuously Burning Pilot Light

Question

Under what circumstances is a constantly (or continuously) burning pilot light prohibited on certain appliances?

Answer

For compliance with the *Standards*, §115 prohibits continuously burning pilot lights for some natural gas burning equipment (this does not include liquefied petroleum gas burning appliances). §115 prohibits continuous pilots on the following types of equipment:

- Household cooking appliances with an electrical supply voltage connection in which each pilot consumes 150 Btu/hr or more
- Pool heaters
- Spa heaters
- Fan type central furnaces

§150 (e) prohibits continuously burning pilot lights for:

- Fireplaces
- Decorative gas appliances
- Gas logs

For compliance with federal and state appliance regulations (which apply to any appliance sold or offered for sale in California), a constant burning pilot light is prohibited on:

- Gas kitchen ranges and ovens with an electric supply cord
- Pool heaters, except those that burn liquefied petroleum gas

2.7 Lighting

The *Standards* have mandatory measures that address:

- Kitchen Lighting
- Bathroom Lighting
- Recessed Lighting

2.7.1 Kitchen Lighting

§150 (k) 1, 3

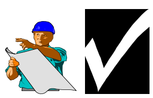
1. *Luminaires for general lighting in kitchens shall have lamps with an efficacy of not less than 40 lumens per watt. General lighting must provide a sufficient light level for basic kitchen tasks and provide a uniform pattern of illumination. A luminaire(s) that is (are) the only lighting in a kitchen will be considered general lighting. General lighting shall be controlled by a switch on a readily accessible lighting control panel at an entrance to the kitchen.*

   Additional luminaires to be used only for specific decorative effects need not meet this requirement.

4. *Luminaires installed to meet the 40 lumens per watt requirements of Section 150(k) 1. or 2. shall not contain medium base incandescent lamp sockets, and shall be on separate switches from any incandescent lighting.*

Installing energy-efficient lamps and fixtures can reduce lighting energy costs without sacrificing the quality or quantity of light available. The intent of the kitchen lighting code is not to increase the number of light fixtures and/or watts used by the occupant but rather to ensure that the builder provides - and the occupant uses - energy efficient lighting. As indicated in Table 2-7, a 40-watt (Full-Size, 4' long) standard fluorescent lamp is over four times as efficient (in terms of efficacy) as a 100-watt standard incandescent lamp (‘efficacy’ is defined in §101(b) of the *Standards* as, “…the ratio of light from a lamp to the electrical power consumed (including ballast losses) expressed in lumens per watt”).

General lighting is the lighting that the occupant will typically use on a regular basis (normally fluorescent lighting, but may be other types with efficacy of 40 lumens per watt or greater). If there is only one light in the kitchen, it is general lighting. The International Society of Illuminating Engineers (IES) guidelines recommend that at least 30 footcandles of light be provided for visual tasks in kitchens. Visual tasks include, but are not limited to, basic kitchen tasks such as preparing meals and washing dishes. These tasks typically occur on accessible kitchen countertops, the tops of ranges and in sinks, where food preparation, recipe reading, cooking, cleaning and related meal preparation activities take place, as well as at the front of kitchen cabinets.



The general lighting in kitchens must:

- Have an efficacy of *at least 40 lumens/watt* (see Table 2-7).
- Provide a uniform pattern of lighting, such as a fixture in the center of the kitchen or around the perimeter (not a fixture in the corner).
- Provide a light level sufficient for performing basic kitchen tasks such as preparing meals and washing dishes.
- Be controlled on a readily accessible switch at an entrance to the kitchen (not in a cupboard or beside the kitchen sink).
- Be switched independent of incandescent lighting.
- Not contain medium-base incandescent lamp sockets. This prevents the occupant from replacing the efficient light source with an incandescent lamp.

Additional luminaires for decorative effect do not need to meet these requirements, however, incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with §150(k)4 (see Recessed Lighting below).

To clearly demonstrate compliance with the *Standards* to a building department, a lighting layout design that includes a point-by-point illuminance grid for the high-efficacy lighting may be provided. To do this properly, this grid must account for the room geometry, fixture placement, photometric data for the fixtures, lamp lumens, lamp lumen depreciation, and reflectivity of all of the surfaces in the kitchen.

Table 2-7 – Typical Efficacy of Electric Lighting Sources

Light Source	Type	Rated Lamp (Watts)	Typical Efficacy (Lumens / Watt)[1]
Incandescent	Standard	40 - 100	14 - 18
Incandescent	Halogen	40 - 250	20[2]
Incandescent	Halogen IR	See footnote [3]	Up to 30
Fluorescent (Lamp/ Ballast Systems)[4]	Full-Size, 4' Long	32 - 40	69 - 91
	U-Shaped T-8 Bipin	16 - 31	78 - 90
	Compact Fluorescent	5 - 9	26 - 38
	Compact Fluorescent	13 +	42 - 58
Metal Halide	Metal Halide	32 - 175	50 - 90
High Pressure Sodium	White High Pressure Sodium	35 - 100	36 - 55

1 Includes power consumed by ballasts where applicable.

2 Halogen capsule incandescent lamps may be the most efficient light source for highlighting applications. Most halogen lamps are designed to produce a beam of directed light. Manufacturer's data typically list the "candlepower" intensity of that beam, rather than lumens (lumens measure total light output in all directions).

3 A new technology using infrared reflecting films on the halogen capsules has increased output up to 30 lumens/watt for some high wattage lamps.

4 Efficacy of fluorescent lighting varies depending on lamp and ballast types.

Example 2-8 – Energy-efficient Kitchen Lighting, General

Question

I want to design and provide an energy efficient kitchen. I especially want the lighting design to provide an aesthetically pleasing appearance, sufficient light for basic kitchen tasks, and be energy efficient while also complying with the Energy Efficiency Standards. What is the recommended practice for achieving this goal?

Answer

It is recommended that the builder use one of the following four ways to show compliance:

1. Design and install only high-efficacy luminaires in the kitchen. This scenario meets the code requirement in the most straightforward manner. When kitchen lighting includes both high-efficacy sources and low-efficacy sources, the design may not meet these requirements. The second through fourth ways of showing compliance apply to kitchens with both high- and low-efficacy sources.
2. Provide at least 1.2 Watts per square foot (total square feet of the accessible kitchen floor and countertop areas) of light from high-efficacy sources, and ensure that, in the judgment of the building department plan checker, the lamps in those fixtures produce a substantially uniform pattern of lighting on kitchen work surfaces (please note that this is not a code requirement but a recommendation).
3. Make sure that at least 50% of the kitchen lighting wattage is high-efficacy, and that, in the judgment of the building department plan checker, the lamps in those fixtures produce a substantially uniform pattern of lighting on kitchen work surfaces (please note that this is not a code requirement but a recommendation).
4. If you wish to be certain you have provided an “energy efficient kitchen…an aesthetically pleasing appearance…sufficient light for basic kitchen tasks…while also complying with the Energy Efficiency Standards,” it is recommended that you use the same procedures used by professional lighting designers (again, the intent of this recommendation is not that these procedures become a standard part of builder submittals, but rather that they are used to provide the best possible solutions for builders who wish to provide high quality lighting designs).

These procedures account for the characteristics of the room and the design and location of the specific high-efficacy luminaires that will be installed as the best method to determine if there is both sufficient and uniform light. A recognized lighting authority, the Illuminating Engineers Society (IES), provides guidelines for good lighting design in their Lighting Handbook, Reference & Application, 10th Edition.

IES guidelines recommend that at least 30 footcandles of light be provided for seeing tasks in kitchens. Visual tasks include, but are not limited to, the basic kitchen tasks that are described in the Energy Commission's *Residential Manual* as preparing meals and washing dishes. These tasks typically occur on accessible kitchen countertops, the tops of ranges and in sinks, where food preparation, recipe reading, cooking, cleaning and related meal preparation activities take place, as well as at the front of kitchen cabinets so that the contents of the cabinet are discernable.

To clearly demonstrate compliance with the *Standards* to a building department, the builder may provide a lighting layout design that includes a point-by-point illuminance grid for the high-efficacy lighting. To do this properly, this grid must account for the room geometry, fixture placement, coefficient of utilization (CU) of the fixtures, lamp lumens, lamp lumen depreciation, and reflectivity of all of the surfaces in the kitchen.

Uniform lighting assures that the minimum amount of light is available on all the work surfaces used in meal preparation and cleanup. Although the design should achieve 30 footcandles on most counter-height, horizontal work surfaces, there may be a few work-surfaces where the lighting levels fall below this value and the fronts of kitchen cabinets may also be below this value. Even in these locations, the lighting level provided by the high-efficacy source should not fall below the IES-recommended lower value for non-critical seeing tasks of 20 footcandles. Parts of counters that are not work surfaces, such as a corner underneath a cabinet, may have a lighting level below 20 footcandles and still meet the requirements of the standard, because meal preparation is unlikely to occur in those areas.

Manufacturers and lighting fixture representatives can often provide such a grid for a specified design. Electrical engineers who do lighting designs and professional lighting designers also often provide designs with a point-by-point illuminance grid.

The plans should identify the type of luminaire and maximum Underwriters Laboratory (UL)-rated lamp watts for each luminaire and should include dimensions and tolerances of each luminaire so that the installer, plan checker, and field inspector can all determine when the lighting installation matches the plan checker's judgment. When calculating the kitchen lighting wattage, the builder should be certain to use the maximum UL-rated wattage for each fixture.

2.7.2 Bathroom Lighting

§150(k)2 - 3

2. *Each room containing a shower or bathtub shall have at least one luminaire with lamp(s) with an efficacy of 40 lumens per watt or greater. If there is more than one luminaire in the room, the high efficacy luminaire shall be switched at an entrance to the room.*

   ALTERNATIVE to Section 150(k)2.: A high efficacy luminaire need not be installed in a bathroom if:

A. *A luminaire with lamps with an efficacy of 40 lumens per watt or greater is installed in a utility room, laundry room, or garage; and*

B. *All luminaires permanently mounted to the residence providing outdoor lighting shall be installed with the following characteristics:*

   (1) *Luminaires with lamps with 40 lumens per watt or greater; or*

   (2) *Luminaires with lamps with an efficacy of less than 40 lumens per watt shall be equipped with a motion sensor.*

Note: *When using this alternative for multiple bathrooms, after complying with B. for the first bathroom, each additional bathroom in which a high efficacy luminaire is not installed must comply with A. alone.*

3. *Luminaires installed to meet the 40 lumens per watt requirements of Section 150(k) 1. or 2. shall not contain medium base incandescent lamp sockets, and shall be on separate switches from any incandescent lighting.*

Each room with a shower or bathtub must have at least one luminaire with lamps with an efficacy of at least 40 lumens/watt. If there is more than one luminaire in the room, the high-efficacy luminaire must be switched at an entrance to the room.

As an alternative, both of the following are required:

1. A luminaire with 40 lumens/watt lamps must be installed in another room with utilitarian functions such as a laundry room, utility room or garage; and

2. All permanently mounted outside lighting must either be at least 40 lumens/watt or equipped with a motion sensor.

When using this alternative for two or more rooms with showers or bathtubs, compliance with item 1 (above) is sufficient for the second or third rooms since the outside lighting is already in compliance with item 2 above.

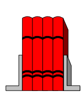
Luminaires installed to meet the 40 lumens/watt requirements cannot contain medium base incandescent lamp sockets, and must be on separate switches from incandescent lighting.

Incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with §150(k)4 (see below).

Installing energy-efficient lamps and fixtures can reduce lighting energy costs without sacrificing the quality or quantity of light available. As indicated in Table 2-2, a 40 watt standard fluorescent lamp is over four times as efficient as a 100 watt standard incandescent lamp.

Incandescent lighting fixtures recessed into insulated ceilings must be IC-rated in compliance with §150(k)4 (see Example 2-9).

2.7.3 Recessed Lighting



§150(k)4

All incandescent lighting fixtures recessed into insulated ceilings shall be approved for zero-clearance insulation cover (I.C.) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials.

All incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with §150(k)4. Although this requirement does not apply to fluorescent fixtures, recessed lighting fixtures left un-insulated significantly increase the heat loss through the roof/ceiling area reducing the effectiveness of the insulation. Heat lamps are not required to be IC-rated.

Example 2-9 – Non-IC Rated Incandescent Fixtures

Question

I'd like to know if it is possible to use non-IC rated incandescent fixtures recessed in an insulated ceiling. Although I've never been able to find a bulb heater (heat lamp) that is IC- rated [approved for insulation cover], they are very popular with my customers. Can I use this product?

Answer

It is possible to build a box of gypsum board or other acceptable interior ceiling finishing material over the fixture so that it is below the boundary of the insulated ceiling. By separating the fixture from being recessed into the insulated ceiling it does not need an IC rating. As long as there is sufficient clearance between the fixture and the interior finishing material to prevent a fire hazard, this assembly is acceptable (recessed fluorescent fixtures do not need to be IC-rated). You can build a box like this to install a non-IC heat lamp or other non-IC rated fixtures.

Question

If insulation is installed between floors of an apartment building (sound-proofing), can I install incandescent fixtures that are not IC-rated?

Answer

No. Although this isn't part of the building envelope, *Standards* §150(k) states that any incandescent fixtures recessed into an insulated ceiling must be approved for zero-clearance insulation cover.

2.8 Compliance Documentation

The Mandatory Measures Checklist (see MF-1R form in Appendix A) is used to show compliance with mandatory measures at the documentation stage. The Installation Certificate and insulation Certificate (see the CF-6R and IC-1 forms in Appendix A) are used to demonstrate compliance at the construction phase. Both of these forms must be made available to the inspector during appropriate inspections, and copies must be provided to the original occupants of the building.

Mandatory Measures Checklist. A sample of the recommended Mandatory Measures Checklist (MF-1R) is included here. More information about the form is included in Chapter 1. Blank forms are contained in Appendix A.

Installation Certificate. A sample of the recommended Installation Certificate (CF-6R) is included here. More information about filling out the form or inspections tied to the form are included in Chapter 1. Blank forms are contained in Appendix A.

Insulation Certificate. A sample of the recommended Insulation Certificate (IC-1) is included here. More information about filling out the form or inspections tied to the form are included in Chapter 1. Blank forms are contained in Appendix A.

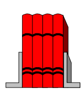
3 Prescriptive Packages

This chapter describes the *Prescriptive Packages* (also referred to as *Alternative Component Packages*). The prescriptive approach is one of two paths available for compliance. The other approach, the Computer Method, is a performance approach and is explained in Chapters 5. This compliance chapter is organized in the following subsections:

- Introduction
- Insulation
- Glazing / Fenestration
- Radiant Barriers
- Thermal Mass (Package C Only)
- Space Conditioning Systems
- Water-Heating Systems
- Compliance Documentation

Additions to existing buildings demonstrating compliance with the prescriptive package approach are discussed in Chapter 7.

3.1 Introduction



§151(f)

Buildings that comply with the prescriptive standards shall be designed, constructed and equipped to meet all of the requirements of one of the alternative packages of components shown in Tables No. 1-Z1 through 1-Z16 for the appropriate climate zone shown in Figure No. 1-A [see Chapter 1, Figure 1-1]. Installed components shall meet the following requirements:

You can comply with the *Standards* by installing a package of building conservation components and measures that make up an *Alternative Component Package*. Each package is a set of pre-defined performance levels for various building components. Each building component must meet or exceed the minimum conservation level specified in the package. There are two packages to choose from: Package C and Package D. The prescriptive packages are the simplest and least flexible compliance path. The only choice involved is the selection of which package to use within the designated climate zone.

Package D

Package D establishes the base prescriptive requirements. Maximum U-factors for fenestration products (windows + framing) is 0.75, 0.65 or 0.60 with colder climates requiring the lower U-factor. Shading requirements vary from no shading in coastal and mountain climates to a maximum 0.40 solar heat gain coefficient (SHGC) in climates with significant air conditioning loads. Only climate zone 16 requires slab edge insulation.

Package D is the reference house for performance compliance. Approved computer programs model a house with the features of Package D to determine the space-conditioning and water-heating budgets. Table 3-1 combines the Package D requirements for all 16 climate zones into one table. This can be used as a guide for assessing how a proposed design compares to this package of features. More detail on each of the requirements follows later in this chapter.

Table 3-1 – Summary of Package D Requirements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BUILDING ENVELOPE																
Insulation minimums[2]																
Ceiling	R38	R30	R30	R30	R30	R30	R30	R30	R30	R30	R38	R38	R38	R38	R38	R38
Walls	R21	R13	R13	R13	R13	R13	R13	R13	R13	R13	R19	R19	R19	R21	R21	R21
“Heavy mass” walls	R4.76	R2.44	R2.44	R2.44	R2.44	R2.44	R2.44	R2.44	R2.44	R2.44	R4.76	R4.76	R4.76	R4.76	R4.76	R4.76
Below-grade walls	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0	R13
Slab floor perimeter	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	R7
Raised floors	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]	R19[2]
Concrete raised floors	R8	R8	R0	R0	R0	R0	R0	R0	R0	R0	R8	R4	R8	R8	R4	R8
Radiant Barrier	NR	REQ	NR	REQ	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
GLAZING																
Maximum U-factor[3]	0.65	0.65	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.65	0.65	0.65	0.65	0.65	0.60
Maximum total area	16%	16%	20%	20%	16%	20%	20%	20%	20%	20%	16%	16%	16%	16%	16%	16%
Solar Heat Gain Coefficient[4]																
South-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
West-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
East-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
North-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
THERMAL MASS[5]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SPACE-HEATING SYSTEM[6]																
Electric-resistant allowed	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
If gas, AFUE =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
If heat pump, split system HSPF[8] =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
Single package system HSPF =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
SPACE-COOLING SYSTEM																
If split system A/C, SEER =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
Refrigerant charge and airflow testing or TXV	NR	REQ*	NR	NR	NR	NR	NR	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	NR
If single package A/C, SEER =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
SPACE CONDITIONING DUCTS																
Duct Sealing	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*
DOMESTIC WATER-HEATING TYPE (System must meet budget, see §151 (b) 1 and (f) 8 and Tables 3-14 to 3-17)	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any	Any

* HERS rater field verification and diagnostic testing are required for this feature. As an alternative under Package D, better glazing and higher efficiency equipment can be used instead of the diagnostic testing of air distribution ducts, split system air conditioners and heat pumps. See Table 3-2 for the increased values, which vary by climate.

NR = Not Required REQ = Required MIN = Minimum

Alternative to Package D

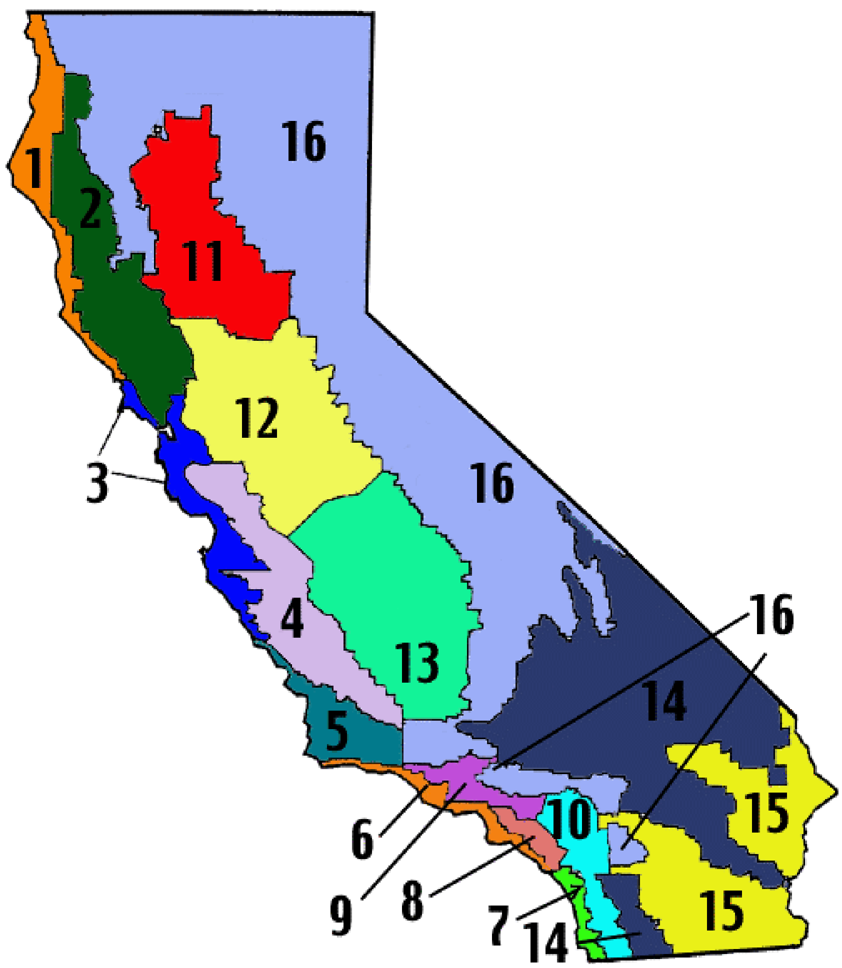
The base Package D requires that a HERS rater come to the building house (at least for a sample of the homes) and perform diagnostic testing to verify that the air distribution ducts are properly sealed and that split system air conditioners or heat pumps either have the proper refrigerant charge and the proper airflow across the evaporator coil or have a thermostatic expansion valve. If the builder does not want to do the field verification and diagnostic testing, then an alternative set of requirements are available that require more energy efficient fenestration and space conditioning equipment (see Table 3-2).

Table 3-2 – Summary of Alternative to Package D Requirements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Window U	0.55	0.40	0.55	0.40	0.55	0.55	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.55
WIndow SHGC	NR	0.35	NR	0.35	NR	NR	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.30	0.30	NR
SEER	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	11.0	11.0	11.0	11.0	12.0	12.0	13.0	MIN
AFUE or	90	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	90
HSPF	7.6	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	7.6

Note: These are alternative Package D prescriptive requirements. If these performance levels are provided, the requirements shown in Table 3-1 with an asterisk are not required. These include diagnostic testing of air distribution ducts, refrigerant charge and airflow and field verification of a thermostatic expansion valve.

Figure 3-1 – California Climate Zones



Package C Package C may be used only if the building is in an area (1) where natural gas is not currently available and (2) where extension of natural gas service is impractical, as determined by the natural gas utility. Among the other Package C features are high performance fenestration products with maximum U-factors of either 0.50 or 0.40. Electric-resistance water heating may be used in conjunction with a solar water-heating system or a wood stove boiler. Slab edge insulation is required in all climate zones. Table 3-3 lists all of the requirements for Package C in all 16 climate zones. More detail on each of the requirements follows.

Table 3-3 – Summary of Package C Requirements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BUILDING ENVELOPE																
Insulation minimums[2]																
Ceiling	R49	R49	R38	R38	R38	R38	R38	R38	R38	R49	R49	R49	R49	R49	R49	R49
Walls	R29	R29	R25	R25	R25	R21	R21	R21	R21	R25	R29	R29	R29	R29	R29	R29
Slab floor perimeter	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7
Floors	R30	R30	R30	R30	R30	R21	R21	R21	R21	R30	R30	R30	R30	R30	R21	R30
Radiant Barrier	NR	REQ	NR	REQ	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
GLAZING																
Maximum U-factor[3]	0.40	0.40	0.40	0.40	0.40	0.50	0.50	0.50	0.50	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Maximum total area	14%	16%	14%	14%	16%	14%	14%	14%	14%	16%	16%	16%	16%	14%	16%	14%
SOLAR HEAT GAIN COEFFICIENT[4]																
South-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
West-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
East-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
North-facing glazing	NR	0.40	NR	0.40	NR	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	NR
THERMAL MASS[5]	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
SPACE-HEATING SYSTEM[6]																
Electric-resistant allowed	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]
If gas, AFUE =	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%
If heat pump, split system HSPF[8] =	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Single package system HSPF =	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
SPACE-COOLING SYSTEM																
If split system A/C, SEER =	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Refrigerant charge and airflow testing or TXV	NR	REQ*	NR	NR	NR	NR	NR	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	NR
If single package A/C, SEER =	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
SPACE CONDITIONING DUCTS																
Duct sealing	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*	REQ*
DOMESTIC WATER-HEATING TYPE	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]	Any[9]
System must meet budget, see §151 (b) 1 and (f) 8																

* HERS rater field verification and diagnostic testing are required for this feature. There is no alternative to Package C field verification and diagnostic testing.

Table 3-4 – Notes To The Low-Rise Residential Packages

See also Table 3-1, Table 3-2 and Table 3-3 (Also Tables 1-Z1 Through 1-Z16 of §151)

[1] Package C is the only package that allows electric-resistance space heating. Package C may be used only if the building is in an area (1) where natural gas is not currently available and (2) where extension of natural gas service is impractical, as determined by the natural gas utility. Package D allows more glazing area in some zones with moderately high insulation levels; slab edge insulation is required in Climate Zone 16.

[2] The R-values shown for ceiling, wood frame wall and raised floor are for wood-frame construction with insulation installed between the framing members. For alternative construction assemblies, see § 151 (f) 1 A.

The heavy mass wall R-value in parentheses is the minimum R-value for the entire wall assembly if the wall weight exceeds 40 pounds per square foot. Any insulation installed on heavy mass walls must be integral with, or installed on the outside of, the exterior mass. The inside surface of the thermal mass, including plaster or gypsum board in direct contact with the masonry wall, shall be exposed to the room air.

[3] For glazing U-factor rating procedures and labeling requirements see §116 (a) 2.

[4] Values specified are maximum allowable values. If the package specifies a solar heat gain coefficient the builder shall meet the requirements of §151 (f) 4.

[5] If the package requires thermal mass, meet the requirements of §151 (f) 5.

[6] Automatic setback thermostats must be installed in conjunction with all space-heating systems in accordance with §151 (f) 9.

[7] Ducts in Package C shall be insulated to an installed value of at least R-8.

[8] HSPF means, "heating seasonal performance factor."

[9] Electric-resistance water heating is allowed as the main water heating source in Package C only if the water heater is located within the building envelope and a minimum of 25 percent of the energy for water heating is provided by a passive or active solar system or a wood stove boiler. The wood stove boiler credit is not allowed in Climate Zones 8, 10, and 15, nor in localities that do not allow wood stoves.

When a HERS Rater is Not Needed

Packages C and D require that air distribution ducts in all climate zones be diagnostically tested by a HERS rater. A HERS rater must also diagnostically test split system air conditioners or heat pumps in climates 2 and 8 through 15 to verify correct refrigerant charge and airflow; alternatively, the HERS rater must verify that the equipment has a thermostatic expansion valve (TXV).

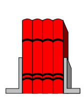
The requirements for field verification and/or diagnostic testing only apply when equipment or systems are installed that require verification or testing. If a house has no air distribution ducts, then a HERS rater does not have to test the ducts, since there are not ducts to test. Similarly, if a house does not have a split system air conditioner or heat pump, then a HERS rater does not have to diagnostically test the refrigerant charge and airflow or verify that there is a TXV, because the requirements do not apply. Likewise, if compliance for a house is achieved using an alternative that does not require a TXV, then a HERS rater does not have to come to the site and verify that one has been installed.

A HERS rater is not required when measures that require field verification or diagnostic testing are not installed in the building. A common situation is when the Alternative to Package D is used (see Table 3-2). Another example is a house with no air conditioning and a heating system that does not have ducts, e.g. hydronic baseboards or radiant panels.

Refer to Section 4.4.2 for details on conditions under which a HERS rater's certification or diagnostic testing is required.

3.2 Insulation

This section presents all the insulation requirements for ceilings, walls, below-grade walls, slab perimeter insulation and raised floors.



§151(f)1

1. *Insulation*

   A. *Ceiling, wall, slab floor perimeter, and raised floor insulation shall be installed which has an R-value equal to or higher than that shown in Tables No. 1-Z1 through 1-Z16. The minimum opaque ceiling, wall (including heated basements* *and crawl spaces), and raised floor R-values shown are for insulation installed between wood framing members.*

ALTERNATIVE to Section 151(f)1A: The insulation requirements of Tables No. 1-Z1 through 1-Z16 may also be met by ceiling, wall, or floor assemblies that meet equivalent minimum R-values that consider the effects of all elements of the assembly, using a calculation method approved by the Executive Director.

EXCEPTION to Section 151(f)1A: Raised floor insulation may be omitted if the foundation walls are insulated to meet the wall insulation minimums shown in Tables No. 1-Z1 through 1-Z16, a vapor barrier is placed over the entire floor of the crawl space, and the vents are fitted with automatically operated louvers.

B. The minimum depth of concrete-slab floor perimeter insulation shall be 16 inches or the depth of the footing of the building, whichever is less.

EXCEPTION to Section 151(f)1B: Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space, covered porches, or covered patios.

The minimum insulation requirements (R-values) for the packages assume that the insulation is installed in the cavity or between wood framing members. When continuous insulation is used, it is better to show compliance by comparing the U-factor of the proposed construction to an equivalent wood framed construction. For example, an R-19 wall may be achieved with either R-19 batt insulation set within 2 x 6 framing, or with R-11 batt insulation placed between 2 x 4 framing plus a minimum of R-4.61 rigid insulation applied to the outside of the framing.

Note: R-value is a minimum; U-factor (the inverse of R-value) is a maximum. A higher R-value is more energy efficient; a lower U-factor is more energy efficient. See the *Glossary* for definitions of *R-Value* and *U-factor*.

For wall, roof, floor and slab insulation, the builder should verify the following:

- All insulation levels meet or exceed the levels indicated on the CF-1R form, which must be on the plans. Insulation levels must also be indicated on the plans independently of the CF-1R.
- The frame type of the envelope must match that specified on the CF-1R form.
- The insulation contractor's must complete the Insulation Certificate (IC-1) and either post it at the job site or make it available to the inspector at appropriate inspections.

The field inspector should check the Certificate of Compliance (CF-1R) form for the required insulation levels and frame type. Check the Insulation Certificate (IC-1) for consistency with the CF-1R. Check that insulation is installed in all wall cavities including narrow cavities between framing members at windows and doors. Check for complete and uniform installation of insulation in all parts of ceilings.

3.2.1 Ceiling Insulation

Specifying the minimum R-value indicated in the selected package can show prescriptive compliance of a wood-frame ceiling. For metal framing or as an alternative to meeting the installed R-value, document the U-factor as specified in Section 2.8. The U-factor of the proposed ceiling assembly must be *less than or equal to* the U-factor of a wood-frame ceiling assembly with the minimum R-value installed. The table below shows the U-factor for typical ceiling insulation systems.

Table 3-5 – Ceiling Assembly U-factors, Wood Frame

Insulation	***Framing/Spacing***	***U-factor***
R-30	2 x 12 / 16” o.c.	0.035
R-30	2 x 10 / 16” o.c.	0.036
R-30	2 x 4 / 24“ o.c.	0.031
R-38	2 x 14 / 16” o.c.	0.028
R-38	2 x 12 / 16” o.c.	0.030
R-38	2 x 4 / 24” o.c.	0.025
R-49	2 x 4 / 16” o.c.	0.019
R-49	2 x 4 / 24” o.c.	0.019

3.2.2 Framed Wall Insulation

Wood framed walls may be shown to comply by specifying the minimum R-value indicated in the selected package. For metal or steel framed walls, or as an alternative to meeting the installed R-value, the designer may document the U-factor. The U-factor of the proposed wall assembly must be *less than or equal to* the U-factor of a wood-frame wall assembly with the minimum R-value installed.

Table 3-6 – Wall Assembly U-factors, Wood Frame

Insulation	***Framing/Spacing***	***U-factor***
R-13	2 x 4 / 16” o.c.	0.088
R-13	2 x 4 / 24” o.c.	0.084
R-19	2 x 6 / 16“ o.c.	0.065
R-19	2 x 6 / 24” o.c.	0.063
R-21	2 x 6 / 16” o.c.	0.059
R-21	2 x 6 / 24” o.c.	0.056

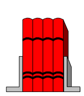
Straw bales that are 23 inches by 16 inches and that have stucco or plaster on the inside and outside vertical surfaces are assumed to have a thermal resistance of R-30. Performance data on other sizes of bales was not available at the time of publication of this *Manual*.

Metal framed assemblies will require rigid insulation in order to meet the maximum U-factor criterion.

Table 3-7 – Steel Frame Wall U-factors

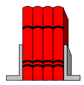
Wall	***Rigid Insulation***	***Framing/ Spacing***	***U-factor***
R-13	0	2 x 4 / 16	0.195
R-13	7	2 x 4 / 16	0.081
R-13	5.28	2 x 4 / 24	0.087
R-15	7	2 x 4 / 24	0.074
R-19	8.8	2 x 6 / 16	0.064
R-19	8.8	2 x 6 / 24	0.060

3.2.3 Mass Wall Insulation



§151(f), footnote 2 to Tables No. 1-Z1 through 1-Z16)

The heavy mass wall R-value in parentheses is the minimum R-value for the entire wall assembly if the wall weight exceeds 40 pounds per square foot. The light mass wall R-value in brackets is the minimum R-value for the entire assembly if the heat capacity of the wall meets or exceeds the result of multiplying the bracketed minimum R-value by 0.65. Any insulation installed on heavy or light mass walls must be integral with or installed on the outside of the exterior mass. The inside surface of the thermal mass, including plaster or gypsum board in direct contact with the masonry wall, shall be *exposed to the room air. The exterior wall used to meet the specified R-value cannot also be used to meet the thermal mass requirement.*



(§101(b))

"HEAT CAPACITY (HC) of an assembly is the amount of heat necessary to raise the temperature of all the components of a unit area in the assembly one degree F. It is calculated as the sum of the average thickness times the density times the specific heat for each component, and is expressed in Btu per square foot per degree F."

Mass walls that have no framing are not required to meet the minimum mandatory wall insulation requirements of §150(c). The R-value listed in Tables No. 1-Z1 through 1-Z16 (in the standard) is the minimum R-value for the entire wall assembly, including insulation and both interior and exterior air films. Where the Package indicates "NA" for a mass wall, the assembly must comply with insulation requirements described for "framed wall insulation." Package D has a special requirement for heavy mass walls (weight greater than 40 lb/ft² of wall surface area). Such walls require R-2.44 in climates 2 through 10 and R-4.76 in the other climates. All other walls (including light mass walls) must have a U-factor equal to or less than a wood wall with the prescribed insulation levels. Table 3-8 has data to help determine wall weight per cubic foot for various materials. The wall thickness needed to meet the requirements of Package D will depend on the weight of the materials used.

Table 3-8 – Thermal Mass Properties

Material	***Density (lb/ft^3)***	***Specific Heat (Btu/lb-°F)***
Adobe	120	0.20
Heavy Concrete	140	0.20
Lightweight Concrete	85	0.20
Gypsum	50	0.26
Masonry Veneer	127	0.20
Masonry Infill	120	0.20
Concrete Masonry Unit	105	0.20
	Grouted Concrete	
Masonry Unit	134	0.20
Stucco	105	0.20
Tile in Mortar	120	0.20
Solid Wood (fir)	32	0.33

3.2.4 Raised Floor Insulation

Exterior raised-floor insulation shall be installed between floor joists with a means of support that prevents the insulation from falling, sagging or deteriorating. Two approaches that accomplish this are:

- Nailing insulation hangers 18 inches apart prior to rolling out the insulation. Hangers are heavy wires up to 48 inches long with pointed ends, which provide positive wood penetration.
- Attaching wire mesh to form a basket between joists to support the insulation. The mesh is nailed or stapled to the underside of the joists.

Controlled Ventilation Crawlspace

The *Standards* exempt the installation of raised-floor insulation if three conditions are met: (1) the foundation walls are insulated to meet the wall insulation minimums of the package, (2) a vapor barrier is placed over the entire floor of the crawl space and (3) the vents are fitted with automatically operated louvers. (See also *Controlled Ventilation Crawl Space* in Appendix G, the *Glossary*.)

Prescriptive compliance of a wood-frame raised floor can be shown by specifying the minimum R-value indicated in the selected package. For metal framing, or as an alternative to meeting the installed R-value, the compliance author must document the U-factor as specified in Section 2.8. The U-factor of the proposed floor assembly must be *less than or equal to* the U-factor of a wood-frame floor assembly with the minimum R-value installed.

Table 3-9 – Floor Assembly U-factors, Wood Frame

Insulation	***Framing/ Spacing***	***Crawl Space***	***U-factor***
R-13	2 x 6 / 16” o.c.	NO	0.064
R-13	2 x 6 / 16” o.c.	YES	0.046
R-19	2 x 8 / 16“ o.c.	NO	0.048
R-19	2 x 8 / 16” o.c.	YES	0.037
R-21	2 x 8 / 16” o.c.	NO	0.045
R-21	2 x 8 / 16” o.c.	YES	0.035
R-30	2 x 10 / 16” o.c.	NO	0.034
R-30	2 x 10 / 16” o.c.	YES	0.028

3.2.5 Concrete Raised Floor Insulation and Below-Grade Walls

When the selected Alternative Component Package requires raised-floor insulation, the requirement may be met by installing insulation with the required R-value or by meeting an equivalent U-factor for all components of the floor assembly. Where the package indicates “N/A” for concrete raised floor insulation, no insulation is required.

When a conditioned space will have concrete walls that are below grade, Alternative Component Package D in climate zone 16 requires R-13 insulation.

3.2.6 Slab Floor Perimeter Insulation

When slab-edge insulation is required, the insulation must be installed to a maximum depth of 16 inches or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the floor line as practical, to the bottom edge of the insulation.

Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space, covered porches or covered patios. Neither would it be practical or necessary to insulate concrete steps attached to the outside slab edge.

In situations where the slab is below grade and slab-edge insulation is being applied to a basement or retaining wall, the top of the slab-edge insulation should be placed as near to ground level as possible and extended down 16 inches. In situations where slab is above grade and slab edge is being applied, the top of the slab-edge insulation should be placed at the top of the slab.

Slab-edge insulation should be protected from physical damage and ultraviolet light exposure. Protection of the slab-edge insulation is important because deterioration from moisture, pest infestation, ultraviolet light exposure and other physical degradation can significantly reduce the effectiveness of the insulation.

3.3 Glazing / Fenestration

3.3.1 Glazing / Fenestration U-factor

§101(b)

FENESTRATION PRODUCT is any transparent or translucent material plus any sash, frame, mullions and dividers, in the envelope of a building, including, but not limited to, windows, sliding glass doors, French doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one half of the door area.

FENESTRATION SYSTEM means a collection of fenestration products included in the design of a building. (See "fenestration product")

FIELD-FABRICATED FENESTRATION PRODUCT OR EXTERIOR DOOR is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

MANUFACTURED FENESTRATION PRODUCT is a fenestration product typically assembled before delivery to a job site. A "knocked-down" or partially assembled product sold as a fenestration product must be considered a manufactured fenestration product and meet the rating and labeling requirements for manufactured fenestration products.

SITE-BUILT FENESTRATION PRODUCTS are fenestration products designed to be field-glazed or field assembled units comprised of specified framing and glazing components. Site-built fenestration is eligible for certification under NFRC 100-SB, and may include both vertical glazing and horizontal glazing.

§151 (f) 3. A.

3. Glazing

A. Installed fenestration products shall have U-factors equal to or lower than those shown in Tables No. 1-Z1 through 1-Z16. The U-factor of installed fenestration products shall be determined pursuant to Section 151 (e) 5.

§ 151 (e) 5

5. The U-factor of installed manufactured fenestration products shall be those certified by an approved independent certification organization in accordance with Section 116. The U-factor of field-fabricated fenestration products shall be those values from Section 116, Table No. 1-D, based on an approved method that determines the area weighted average U-factor for generic types of products.

Each Alternative Component Package establishes a maximum U-factor for all the fenestration products in the building. This includes skylights, doors with more than one-half the door area as glass, and windows. Each window, glass door or skylight must have a U-factor less than or equal to that specified in the selected package. If any of the fenestration products has a higher U-factor, the building does not comply with the prescriptive approach.

The U-factor criterion applies to both windows and skylights. Refer to Section 8.4 for more information on fenestration products. Section 8.4 also addresses bay windows.

The U-factor of each fenestration product being installed must be *equal or lower than* that specified on the plans and CF-1R. An Installation Certificate (CF-6R) is completed for the fenestration products installed.

Check the Certificate of Compliance (CF-1R) form for the required fenestration U-factor. Compare this against the CF-6R for the U-factor of installed products.

3.3.2 Maximum Glazing / Fenestration Area

§151(f) 3 B.

B. Total glazing area shall not exceed the percentage of conditioned floor area specified in Tables No. 1-Z1 through 1-Z16.

The prescriptive packages limit the total area of fenestration products in the building. Package D limits glazing area to 20% of the floor area in climates 3, 4 and 6 through 10; 16% is permitted in the other climate zones. Package C permits either 14% or 16%, depending on climate zone. With the prescriptive packages, there is no restriction with regard to the orientation of the glass. Skylight area is included in the maximum glazing percentage. Maximum glazing is expressed as a percent (%), representing the total area of fenestration products (in square feet) divided by the total conditioned floor area, then multiplying by 100 (see *Fenestration Area* in the *Glossary*).

$$\frac{\text{Fenestration (ft}^2\text{)}}{\text{Floor Area (ft}^2\text{)}} \times 100 = \%\text{ fenestration}$$

The area of glass shown on the CF-1R is the maximum amount that can be installed without demonstrating that the total area of glass in the building is within the percentage allowed by the package used for compliance.

Complete the fenestration portion of the CF-6R. Compare the installed glass area both visually and as indicated on the CF-6R with the allowed glass areas indicated on the CF-1R. If more glass is installed, it must be demonstrated that the building does not exceed the glass area allowed by the prescriptive approach. Without such proof, the building is not in compliance with the *Standards*.

3.3.3 Shading

Where Tables No. 1-Z1 through 1-Z16 require a solar heat gain coefficient of 0.40 or lower, the requirements shall be met by either:

§151 (f) 4

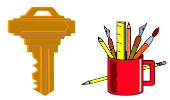
A. A fenestration product listed by the manufacturer to have the required solar heat gain coefficient; or

B. An exterior operable louver or other exterior shading device that meets the required solar heat gain coefficient; or

C. A combination of exterior shading device and fenestration product to achieve the same performance as achieved in A.

D. For south-facing glazing by optimal overhangs installed so that the south-facing glazing is fully shaded at solar noon on August 21 and substantially exposed to direct sunlight at solar noon on December 21.

Except where the UBC requires emergency egress, exterior shading devices must be permanently attached to the outside of the structure with fasteners that require additional tools to remove (as opposed to clips, hooks, latches, snaps or ties).



Solar heat gain coefficient (SHGC) is a measure of the effectiveness of fenestration in rejecting solar heat gain (see *Shading* in the *Glossary*). The SHGC is a fractional value that ranges between 0 and 1. A *higher value indicates less shading effectiveness* with a greater amount of solar radiation penetrating the combined glazing/ frame/shade assembly and absorbed as heat. *A lower SHGC value corresponds to better shading effectiveness* with less solar gain making its way into the building.

Fenestration products are required to have a SHGC of 0.40 or less in the California climates with a significant cooling load (all except 1, 3, 5, 6, and 16). SHGCs listed for the prescriptive packages represent maximum values not to be exceeded for movable shading devices or intrinsic shading properties of the fenestration product. When the prescriptive packages show "NR", no specific shading needs to be installed. The requirements for an SHGC of 0.40 or less may be met by a window, skylight or other fenestration unit that the manufacturer certifies to have the required SHGC, or by installing an exterior shading device, or by some combination of the two.

Note: Interior shading devices other than the default may *not* be used to achieve compliance with the required SHGC.

To determine compliance with prescriptive requirements for a maximum SHGC, options include constructing an optimal overhang (see below) or using a value from:

- Chapter 2 of this *Manual* Table 2-3 – Default Solar Heat Gain Coefficients (From Table 1-E of §116 of the Standards) for default SHGC values for fenestration products.
- Product literature for the proposed fenestration product(s) showing a value equal or lower than required by the Alternative Component Package selected.
- Table 3-10 – Allowed Solar Heat Gain Coefficients Used for Form S for SHGC values of exterior shading devices.
- Form S calculations showing the combined $SHGC_{shade\ open}$ is less than the target value for the proposed fenestration and one of the exterior devices listed in Table 3-1. This target value is determined from a Form S calculation for an $SHGC_{fenestration}$ of 0.40 with default bugscreen exterior shading. Refer to *Shading* in the *Glossary* for an explanation of how to calculate a Form S SHGC for different combinations of exterior devices and glass types.

***Note:** To gain credit for exterior shades, they must be permanently attached to the outside of the residence with fasteners that require additional tools to remove (as opposed to clips, hooks, latches, snaps or ties). Exterior shades on windows or skylights that are prohibited by the UBC from being permanently attached for emergency egress reasons are exempt from this requirement.*

Table 3-10 – Allowed Solar Heat Gain Coefficients Used for Form S

Exterior Shading Device	***SHGC***
Bug Screen (default)	0.76
Woven SunScreen	0.30
Louvered SunScreen	0.27
Low Sun Angle Sunscreen	0.13
Roll-down Awning	0.13
Roll -down Blinds or Slats	0.13
None (skylights only/skylight default)	1.00

Shading requirements for south glazing can also be met by installing any overhang that completely shades the glazing at solar noon on August 21st and substantially exposes the glazing to direct sunlight at solar noon on December 21st. Any well-designed overhang, designed to meet this performance specification, may be used when shading is required for south glazing.

When shading is required, it is specified on the CF-1R form that must be on the plans and must be constructed or installed as specified for the building to be in compliance with the prescriptive approach. The only alternative to installing an exterior shading device or constructing an overhang used to achieve compliance is to install a fenestration product with an equal or lower SHGC value as specified on the CF-1R.

With the prescriptive approach, there are two options for compliance:

- Shading devices or overhangs specified on the CF-1R must be installed.
- Install a fenestration product with an equal or lower SHGC value as shown on the CF-1R.

3.4 Radiant Barriers

(§101(b), 151(f)2)

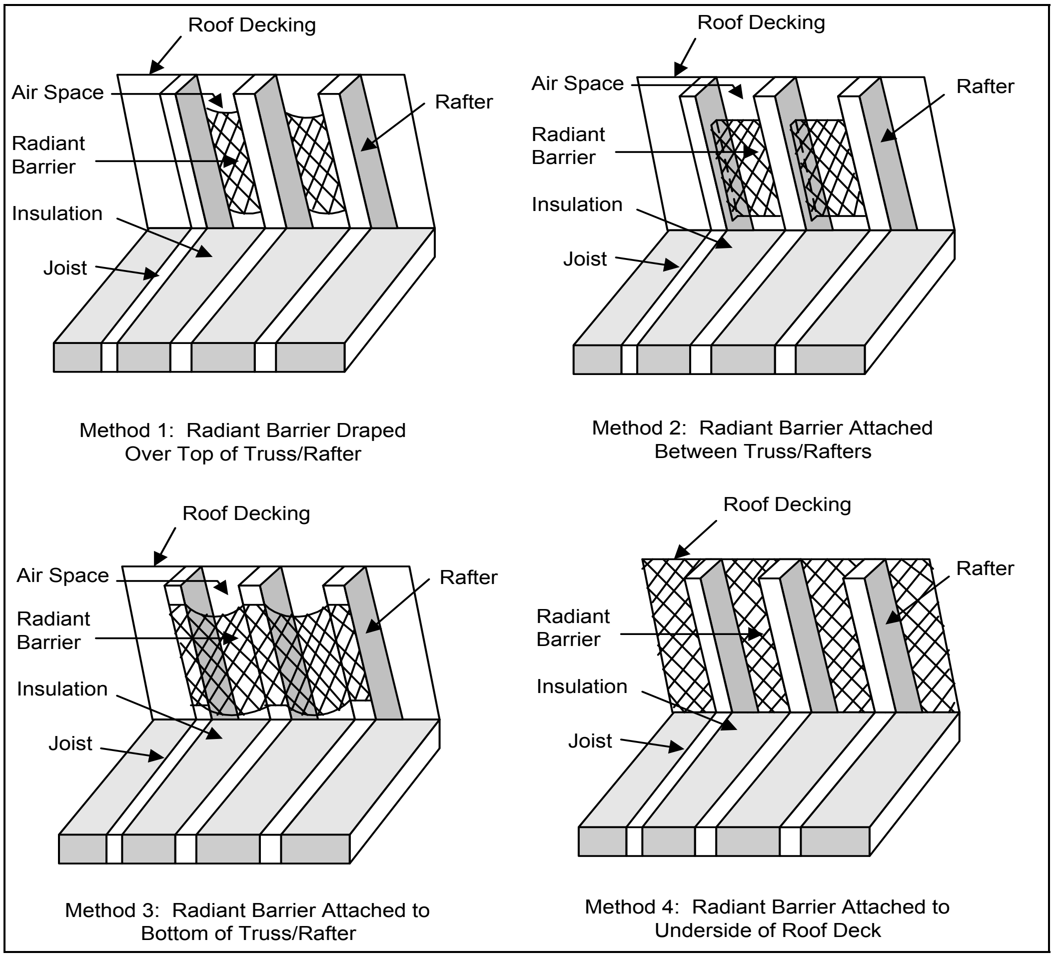
RADIANT BARRIER is any reflective material that has an emittance of 0.05 or less, tested in accordance with ASTM C-1371-98 or ASTM E408-71(1996)e1, and is certified to the California Department of Consumer Affairs as required by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.

§151(f)2

Radiant Barrier. A radiant barrier required in Tables 1-Z1 through 1-Z16 is any reflective material that has an emittance of 0.05 or less, tested according to ASTM C-1371-98 or ASTM E408-71(1996)e1, and that is certified to the Department of Consumer Affairs as required by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.

A radiant barrier is required for roofs in climate zones with significant cooling loads (2, 4, and 8 through 15). The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain to the roof. This reduces the radiant gain to ducts and insulation located below the radiant barrier.

Figure 3-2 – Methods of Installation for Radiant Barriers



Requirements from ACM

The Residential ACM Manual describes the radiant barrier installation requirements as follows:

Radiant barriers must meet specific eligibility and installation criteria to be modeled by any ACM and receive energy credit for compliance with the energy efficiency standards for low-rise residential buildings.

- *The emittance of the radiant barrier must be less than or equal to 0.05 as tested in accordance with ASTM C-1371-98 or ASTM E408-71(1996)e1.*
- *Installation must be in conformance with ASTM C-1158-97 (Standard Practice For Use and Installation Of Radiant Barrier Systems (RBS) In Building Construction.), ASTM C-727-90(1996)e1 (Standard Practice For Installation and Use Of Reflective Insulation In Building Constructions.), ASTM C1313-975 (Standard Specification for Sheet Radiant Barriers for Building Construction Applications), and ASTM C-1224-99 (Standard Specification for Reflective Insulation for Building Applications) and the radiant barrier must be securely installed in a permanent manner with the shiny side facing down toward the attic floor. Moreover, radiant barriers must be installed to the roof truss/rafters (top chords) in any of the following methods, with the material:*

    1. *Draped over the truss/rafter (the top chords) before the upper roof decking is installed.*
    2. *Spanning between the truss/rafters (top chords) and secured (stapled) to each side.*

3. *Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space must be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.*
4. *Attached [laminated] directly to the underside of the roof decking. The radiant barrier must be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.*

In addition, the radiant barrier must be installed to cover all gable end walls and other vertical surfaces in the attic.

- *The attic must be ventilated to:*
  1. *conform to manufacturer's instructions.*
  2. *provide a minimum free ventilation area of not less than one square foot of vent area for each 150 square feet of attic floor area.*
  3. *provide no less than 30 percent upper vents.*

     (Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full air flow to the venting.)
- *The radiant barrier (except for radiant barriers laminated directly to the roof deck) must be installed to:*
  1. *have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier.*
  2. *have a minimum of six (6) inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier.*
- *When installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters, a minimum air space of 1 inch must be provided between the radiant barrier and the top of the ceiling insulation, and ventilation must be provided for every rafter space. Vents must be provided at both the upper and lower ends of the enclosed rafter space.*
- *The product must meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.*

The use of a radiant barrier and the criteria specified above for covering all gable end walls and other vertical surfaces in the attic, and for providing attic ventilation shall be listed in the Special Features and Modeling Assumptions listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement.

For the heating season, Equation 4.1 is the expression for the U-value modifier; for the cooling season, Equation 4.2. To determine the U-value for a ceiling with a radiant barrier, multiply the U-value of the ceiling assembly without the radiant barrier times the U-value modifier. The U-value modifiers are calculated from equations 4.1 and 4.2.

For installed insulation greater than R-8:

$$\mathrm{UvalMod}_{\mathrm{Heating}} = (-11.404 \times U^2) + (0.21737 \times U) + 0.92661 \qquad \text{Equation 4.1}$$

$$\mathrm{UvalMod}_{\mathrm{Cooling}} = (-58.511 \times U^2) + (3.22249 \times U) + 0.64768 \qquad \text{Equation 4.2}$$

Otherwise, these modifiers are 1.000.

Radiant Barriers in Closed rafter Spaces

Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces. A minimum vent area of one square foot is required for each 150 square feet of attic floor area. This ratio may be reduced to 1 to 300 if a ceiling vapor retarder is present or if high (for example, ridge or gable vents) and low (soffit vents) attic ventilation is used. Since part of the vent area is blocked by meshes or louvers, the net free area of a vent must be considered for meeting ventilation requirements. It is difficult to achieve uninterrupted air movement in closed rafter spaces and to meet the minimum ventilation requirements making such spaces more prone to moisture damage compared to open attic spaces. Also radiant barriers must 'see' air spaces this places more restrictions on installing them in closed rafter spaces. In closed rafter spaces, the depth of the rafters severely limits the provision of this gap. Rafters used in home construction are usually not large enough to provide the proper amount of insulation to fit in the cavity between the rafters and still have a ventilation space. Both are required to have an energy efficient building envelope. The depth of the rafters dictates a certain volume of space that can be filled with only so much insulation and still have an air space at the top for natural ventilation. 10 inches thick batt insulation in 2x12 rafters leaves less than 2 inches for air movement and installing radiant barriers.

There are two primary choices of radiant barrier placement in the cathedral ceiling design. The radiant barrier can be draped over the rafter or attached to the bottom of the decking. Ensure adequate ventilation by providing continuous venting through the sides and protecting this opening by overhangs.

Check the Certificate of Compliance (CF-1R) to see if a radiant barrier is required and review form IC-1 (Insulation Certificate) for consistency. Check that the radiant barrier is installed with the shiny side facing the attic air space.

3.5 Thermal Mass (Package C Only)

§151(f)4

Thermal mass required for Package C in Tables No. 1-Z1 through 1-Z16 shall meet or exceed the minimum interior mass capacity specified in Table No. 1-U [Table 3-11].:

Table 3-11 – Interior Mass Capacity Requirements for Package C

Floor Type	Minimum Interior Mass Capacity
C (slab floor)	2.36 X Ground Floor Area (ft²)
C (raised floor)	0.18 X Ground Floor Area (ft²)

The mass requirements in the above table may be met by calculating the combined interior mass capacity of the mass materials using Equation 3-1.

Calculation of Interior Mass Capacity

Equation 3-1

$$IMC = [(A_1 \times UIMC_1) + (A_2 \times UIMC_2) + (A_n \times UIMC_n)]$$

Where,

A_n = Area of mass material n, and

$UIMC_n$ = Unit Interior Mass Capacity of mass material n

Note: Table 3-12 and Table 3-13 of the Commission's *Residential Manual* list the Unit Interior Mass Capacity (UIMC) of various mass materials.

Thermal mass stores heat as a house warms and slowly releases the stored heat as the house cools. This helps moderate temperature variations within the space and reduces the need to use heating and cooling equipment. Typical materials that are most effective as thermal mass include: concrete, tile, brick and other materials with high Unit Interior Mass Capacities (UIMC) as listed in Table 3-12 and Table 3-13.

Thermal Mass is NOT required for Package D, only for compliance with Package C. The table above lists the minimum Interior Mass Capacity required for Package C. Note that Package C requirements are based on the building Ground Floor Area and the floor type. See the Glossary for the definition of Ground Floor Area for slab and raised-floor buildings.

The Interior Mass Capacity (IMC) of a material is calculated by multiplying its Area times its Unit Interior Mass Capacity (UIMC). Table 3-12 and Table 3-13 list the UIMCs for a number of thermal mass materials. The prescriptive thermal mass requirements may be met by adding the IMCs of all mass elements in the building.

This method allows for multiple mass types in both raised-floor and slab-on-grade construction. The Thermal Mass Worksheet (WS-1R) works through Equation 3-1 to calculate the IMC. On the WS-1R, describe each interior mass surface and enter its area and UIMC value (see Table 3-12 and Table 3-13). For each surface, multiply the surface area by the UIMC and add the results of all mass elements.

3.5.1 Slab Floor Interior Mass

The interior mass requirement for Package C slab-floor buildings is comparable to having 20% of the *ground floor slab area* exposed to the conditioned space. This assumes a standard weight (140lb/ft^3) concrete slab at least 3.5 inches thick. A Package C slab-floor building may meet its thermal mass requirement by either calculating the IMC of all of the mass elements in the building, or by exposing 20% of a 3.5-inch concrete slab.

Table G-13 (in the Appendix) contains a complete list of floor coverings that qualify as *exposed* mass. This list includes brick, ceramic tile, stamped concrete (acceptable in any location), vinyl tile, sheet vinyl and unfinished concrete (only when located in kitchens, dining areas, pantries, bathrooms, laundry rooms, service porches and entries).

3.5.2 Raised Floor Interior Mass

The interior mass requirement for Package C raised-floor buildings is based on having mass equivalent in performance to 5% of the ground floor area consisting of exposed two-inch thick concrete slab with a volumetric heat capacity of 28, a conductivity of 0.98, a surface conductance of 1.3 and no thermal resistance on the surface. The heat capacity and conductivity performance equivalent referred to is that of standard 140 lb/ft^3 concrete.

Table 3-12 – Interior Mass UIMC Values: Interior Mass[9] - Surfaces Exposed on One Side[10]

Material	***Surface Condition***	***Mass Thickness (inches)***	***Unit Interior Mass Capacity***
Concrete	Exposed[1]	2.00	3.6
Slab-on-Grade and		3.50	4.6
Raised Concrete Floors		6.00	5.1
	Covered[2]	2.00	1.6
		3.50	1.8
		6.00	1.9
Lightweight Concrete[8]	Exposed	0.75	1.0
		1.00	1.4
		1.50	2.0
		2.00	2.5
	Covered	0.75	0.9
		1.00	1.0
		1.50	1.2
		2.00	1.4
Solid Wood	Exposed	1.50	1.2
		3.00	1.6
Tile[3,]	Exposed	0.50	0.8
		1.00	1.7
		1.50	2.4
		2.00	3.0
Masonry[4,8]	Exposed	1.00	2.0
		2.00	2.7
		4.00	4.2
Adobe[8]	Exposed	4.00	3.8
		6.00	3.9
		8.00	3.9
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.1
	1.00" Gypsum	na	0.5
	0.88" Stucco	na	1.1
Masonry Infill[7]	0.50" Gypsum	3.50	1.3

Table 3-13 – Interior Mass UIMC Values: Interior Mass[9] - Surfaces Exposed on Two Sides[5, 10]

Material	Surface Condition	Mass Thickness (inches)	Unit Interior Mass Capacity
Partial Grout	Exposed[1]	4.00	6.9
Masonry[4]		6.00	7.4
		8.00	7.4
Solid Grout	Exposed	4.00	8.3
Masonry[4,6]		6.00	9.2
		8.00	9.6
Adobe	Exposed	4.00	7.6
		12.00	7.8
		16.00	7.6
Solid Wood/	Exposed	3.00	3.3
Logs		4.00	3.3
		6.00	3.3
		8.00	3.3
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.2
	1.00" Gypsum	na	0.9
	0.88" Stucco	na	2.1
Masonry Infill[7]	0.50" Gypsum	3.50	2.6

Notes For Table 3-12 and Table 3-13

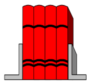
1. "Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.
2. "Covered" includes carpet, cabinets, closets or walls.
3. The indicated thickness includes both the tile and the mortar bed, when applicable.
4. Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry materials.
5. The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.
6. "Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.
7. The indicated thickness for masonry infill is for the masonry material itself.
8. Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.
9. When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.
10. Values based on properties of materials listed in 1993 *ASHRAE Handbook of Fundamentals.*

The builder should install mass materials and exposed surfaces in accordance with the thermal mass requirements shown on the CF-1R. When the CF-1R shows Package C was used, it is important that the material type and area in the building be consistent with those shown on the form. Field changes could result in the building not complying with the prescriptive approach. If changes occur, it will be necessary to recalculate thermal mass compliance for the entire building with a different compliance approach.

With the Package C prescriptive approach, there are three possibilities:

- Thermal mass is consistent with the specifications on the CF-1R for mass materials, including floors covered or exposed, or
- The “as built” thermal mass conditions are checked for compliance with the prescriptive package selected; or
- The calculations are resubmitted to demonstrate compliance with a different compliance approach.

3.6 Space Conditioning Systems



§151(f) 6, 7, 9, and 10

6. *Heating System Type. Heating system types shall be installed as required in Tables No. 1-Z1 through 1-Z16. A gas heating system is a natural or liquefied petroleum gas heating system.*

7. *Space Heating and Space Cooling. When refrigerant charge and airflow measurement or thermostatic expansion valves are shown as required by Tables 1-Z1 through 1-Z16, ducted split system central air conditioners and ducted split system heat pumps shall either have refrigerant charge and airflow measurement confirmed through field verification and diagnostic testing in accordance with procedures set forth in the ACM Manual or shall be equipped with thermostatic expansion valve (TXV) with an access door or removable panel to verify installation of the TXV. All TXVs shall be confirmed through field verification and diagnostic testing as specified in the ACM Manual. All space heating and space cooling systems must comply with minimum appliance efficiency standards as specified in §110-§112.*

9. *Setback Thermostats. All heating systems shall have an automatic thermostat with a clock mechanism or other setback mechanism approved by the Executive Director which the building occupant can manually program to automatically set back the thermostat set points for at least 2 periods within 24 hours. The exception to §150(i) shall not apply to any heating system installed in conjunction with the packages specified in Tables No. 1-Z1 through 1-Z16.*

10. *Space conditioning ducts. All supply ducts shall either be in conditioned space or be insulated to a minimum installed level of R-4.2 and constructed to meet minimum mandatory requirements of §150(m). All duct systems shall be sealed, as confirmed through field verification and diagnostic testing, in accordance with procedures set forth in the ACM Manual.*

All heating systems must also comply with the mandatory measures explained in Chapter 2, including sizing according to design heating loads (see Section 2.5.2).

3.6.1 Gas Systems

All packages require that gas space-heating systems meet the minimum *Appliance Efficiency Regulations.* Package C additionally specifies a minimum of 78% Annual Fuel Utilization Efficiency (AFUE). Package D does not specify a minimum efficiency, allowing any gas space-heating device, including non-central furnaces, to be installed. See *AFUE* in the *Glossary* for a discussion of gas heating efficiency requirements.

3.6.2 Heat-Pump Systems

All heat pumps installed with the prescriptive packages must meet minimum appliance efficiency requirements. Package C limits split system air source heat pumps to a Heating Seasonal Performance Factor (HSPF) rating of 6.8 or higher. Single package air source heat pumps must have an HSPF rating of at least 6.6. Package D does not specify a minimum efficiency, allowing any heat pump, including non-central, to be installed.

3.6.3 Electric Resistance Heating

Electric resistance and electric radiant heating systems are allowed only in Package C. Package C may only be used for compliance if:

- The building is located in an area where natural gas is not currently available; and
- The local natural gas utility determines it is not practical to extend natural gas service to the site.

There are no minimum appliance efficiency standards for electric-resistance or electric-radiant heating systems.

3.6.4 Other Space-Heating Systems

Solar space-heating systems are not recognized within the prescriptive packages.

Wood heat is allowed with prescriptive compliance, provided all conditions as explained in Section 8.5 are met.

3.6.5 Space Cooling System Type

Air conditioners and the cooling cycle of heat pumps must meet or exceed the Seasonal Energy Efficiency Ratio (SEER) required by Package C. The value listed is the minimum established by the *Appliance Efficiency Regulations* for both split system and single package air conditioners or heat pumps. Split system air conditioners must have a minimum SEER of at least 10.0. The minimum SEER requirement for single package air conditioners is 9.7. Package D does not specify a minimum efficiency, allowing any space cooling device, including non-central units, to be installed.

3.6.6 Refrigerant Charge and Air Flow Measurement

The measurement and regulation of refrigerant charge and airflow can significantly improve the performance of air conditioning equipment. Refrigerants are the working fluids in air conditioning and heat pumps systems that absorb heat energy from one area (the evaporator) and transfer it to another (the condenser). This is accomplished through evaporation and condensation of the refrigerant for heat absorption and rejection respectively. Refrigerant charge refers to the actual amount of refrigerant present in the system. Excessive refrigerant charge can lead to premature compressor failure and insufficient charge can cause compressors to overheat. In dry climates such as California, high airflow rates can increase the sensible capacity and total capacity and will increase the EER. Low airflow rates can lead to ice buildup on the cooling coil and compressor failure. The prescriptive standards require that a HERS rater verify that split systems have the correct refrigerant charge. See Section 4.3 and Appendix L for more information.

3.6.7 Thermostatic Expansion Valves

Thermostatic expansion valves (TXV) may be used as an alternative to diagnostic testing of the refrigerant charge and airflow across the coils. See Figure 3-3. TXVs are used in air conditioners or heat pumps to control the flow of refrigerant into the evaporator in response to the superheat of the refrigerant leaving it. The valve is placed upstream from the evaporator inlet and is connected to a temperature-sensing bulb and, when an external pressure bleed is used, a pressure tap located at the evaporator outlet. As the gaseous refrigerant leaves the evaporator the TXV senses its temperature and pressure (superheat) and adjusts the flow rate to maintain proper conditions. Eligible systems must provide a removable door for valve verification and testing by a certified HERS rater. An access door (or removable panel) is not required if the TXV is located outside the box. Package D requires either a TXV or testing of refrigerant charge and airflow in climate zones 2 and 8 through 15.

Figure 3-3 – Thermostatic Expansion Valve

3.6.8 Setback Thermostat

The prescriptive requirements (both Package C and D) require that all systems have a setback thermostat. The thermostat must have a clock or other mechanism, which allows the building occupant to schedule the heating and/or cooling setpoint temperature over a 24-hour period of time. In performance calculations, the budget building always has a setback thermostat, so there is an energy penalty if the proposed design does not have one. The setback thermostat must be designed so that the building occupant can program different temperature settings for at least two different time periods each day, for example, 68 °F during morning hours, 60 °F during the day, 68 °F during evening hours, and 60 °F at night.

An automatic setback thermostat is also a mandatory measure required for all space conditioning systems (see Section 2.5.3). However, there are exceptions to the mandatory measures for certain systems.

3.6.9 Ducts

For Package D, only the minimum R-4.2 duct insulation must be installed – a mandatory measure. However, Package C requires a minimum duct insulation of R-8. All duct systems shall be sealed, as confirmed through field verification and diagnostic testing, in accordance with procedures set forth in the ACM Manual. These procedures are described in Section 4.1 and Appendix J.

3.6.10 Documentation and Compliance

The builder should install:

- Equipment type as specified on the CF-1R
- Equipment efficiency as specified on the CF-1R
- Duct insulation as specified on the CF-1R
- Ducts in accordance with mandatory construction requirements from Section 2.5.7

The builder should:

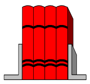
- Obtain a Certificate of Field Verification and Diagnostic Testing (CF-4R) from a HERS rater for features that require field verification and diagnostic testing.
- Complete or obtain from the installer an Installation Certificate (CF-6R) for installed equipment.

Check the CF-1R for required measures and the CF-6R for installation information. The following are acceptable changes:

- Installing a heat pump instead of gas-heating equipment.

- Installing gas-heating equipment instead of a heat pump.

3.7 Water-Heating Systems



§ 151(b)1 and (f)8

Section 151(f)8:

All water heating systems must meet the water heating budgets calculated from Equation No. 1-N.

NOTE to Section 151(f)8.: Any gas type domestic water heater of 50 gallons or less, which is certified as meeting the Appliance Efficiency Standards, and which meets tank insulation requirements of 150(j) may be assumed to meet the water heating budget.

Section 151(b)1:

The annual water heating budget calculated from Equation No. 1-N may be met by either:

A. Calculating the energy consumption of the proposed water heating system using an approved calculation method without an external insulation wrap or

B. Installing any gas storage type non-recirculating water heating system that does not exceed 50 gallons of capacity, and that meets the minimum standards specified in the Appliance Efficiency Standards.

Note: Storage gas water heaters with an energy factor of less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater in accordance with §150(j).

All packages, except Package C, require that the installed water-heating system meet the water-heating energy budget. This means one 50-gallon or less, gas storage type water heater, non-recirculating. If the energy factor is below 0.58 (i.e., 0.53 - 0.579) an R-12 external insulation blanket is a mandatory requirement.

If the water-heating system is other than described in the previous paragraph, Table 3-14 through Table 3-17 list other water-heating systems that have been pre-calculated to meet the water-heating budget for residences. Those systems that comply are designated with a "Y"; systems that do not comply are designated with a "N".

Note: Interpolation is not allowed when using Table 3-14 through Table 3-17. If a water-heating efficiency falls between values on the table, use the lower value.

The remaining alternative is to show compliance with the water-heating budget as explained in Chapter 6.

Package C

Package C water-heating system complies if it meets the budget as explained above or by installing an electric-resistance water heater that is:

- Located within the building envelope; and
- Supplemented by either a solar water-heating system or a wood stove boiler, which provides at least 25% of the residence's water heating requirements. See Chapter 6 for documentation requirements and installation criteria for active and passive solar water-heating systems and wood stove boilers. The wood stove boiler credit is not allowed in Climate Zones 8, 10 or 15, or in other jurisdictions, which do not allow wood stoves.

Table 3-14 – Complying Water Heating Systems[1] – One Water Heater - No Auxiliary Credits

Water Heater Type[2]	CZ	Energy Factor	Distribution[3]			Recirculating Systems		
			STD	HWR POU	Pipe Insulation	No Control	Temp/ Timer	Demand/ Temp
SG50	All	0.53	Y[4]	Y	Y	N[4]	N	Y
		0.63	Y	Y	Y	N	Y	Y
		0.73	Y	Y	Y	Y	Y	Y
SG75	All	0.48	N	Y	N	N	N	N
		0.58	Y	Y	Y	N	N	Y
		0.68	Y	Y	Y	Y	Y	Y
SE	All	0.87	N	N	N	N	N	N
		0.93	N	N	N	N	N	N
IG[6]	All	0.80	Y	Y	Y			
IE	All	0.93	N	N				
HP	1,14	1.80	Y	Y	Y	N	N	Y
		2.20	Y	Y	Y	N	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	2-5,12	1.80	Y	Y	Y	N	N	Y
		2.20	Y	Y	Y	N	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	6-11 & 13, 15	1.80	Y	Y	Y	N	N	Y
		2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	16	1.80	N	N	N	N	N	N
		2.20	N	N	N	N	N	N
		2.60	Y	Y	Y	N	N	Y

Table 3-15 – Complying Water Heating Systems[1] – One Water Heater - Solar Credits[5]

Water Heater Type[2]	CZ	Energy Factor	Distribution[3] STD	HWR POU	Pipe Insulation	Recirculating Systems No Control	Temp/ Timer	Demand/ Temp
SG50	All	0.53	Y	Y	Y	Y	Y	Y
		0.63	Y	Y	Y	Y	Y	Y
		0.73	Y	Y	Y	Y	Y	Y
SG75	All	0.48	Y	Y	Y	Y	Y	Y
		0.58	Y	Y	Y	Y	Y	Y
		0.68	Y	Y	Y	Y	Y	Y
SE	All	0.87	N	Y	Y	N	N	Y
		0.93	Y	Y	Y	N	N	Y
IG[6]	All	0.80	Y	Y	Y			
IE	All	0.93	Y	Y				
HP	1,14	1.80	Y	Y	Y	Y	Y	Y
		2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	2-5,12	1.80	Y	Y	Y	Y	Y	Y
		2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	6-11&	1.80	Y	Y	Y	Y	Y	Y
	13, 15	2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	16	1.80	Y	Y	Y	N	N	Y
		2.20	Y	Y	Y	N	Y	Y
		2.60	Y	Y	Y	Y	Y	Y

Table 3-16 – Complying Water Heating Systems[1] – Two Water Heaters – No Auxiliary Credits

Water Heater Type[2]	CZ	Energy Factor	Distribution[3] STD	HWR POU	Pipe Insulation	Recirculating Systems No Control	Temp/ Timer	Demand/ Temp
SG50	All	0.53	N	N	N	N	N	N
		0.63	Y	Y	Y	N	N	Y
		0.73	Y	Y	Y	Y	N	Y
SG75	All	0.48	N	N	N	N	N	N
		0.58	N	Y	Y	N	Y	Y
		0.68	Y	Y	Y	N	Y	Y
SE	All	0.87	N	N	N	N	N	N
		0.93	N	N	N	N	N	N
IG[6]	All	0.80	N	N	N			
IE	All	0.93	N	N				
HP	1,14	1.80	N	N	N	N	N	N
		2.20	Y	Y	Y	N	N	Y
		2.60	Y	Y	Y	N	Y	Y
HP	2-5,12	1.80	N	Y	N	N	N	Y
		2.20	Y	Y	Y	N	N	Y
		2.60	Y	Y	Y	N	N	Y
HP	6-11 & 13, 15	1.80	N	Y	Y	N	N	Y
		2.20	Y	Y	Y	N	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	16	1.80	N	N	N	N	N	N
		2.20	N	N	N	N	N	N
		2.60	N	N	N	N	N	N

Table 3-17 – Complying Water Heating Systems[1] – Two Water Heaters – Solar Credits[5]

			Distribution[3]			Recirculating Systems		
Water Heater Type[2]	**CZ**	**Energy Factor**	**STD**	**HWR POU**	**Pipe Insulation**	**No Control**	**Temp/ Timer**	**Demand/ Temp**
SG50	All	0.53	Y	Y	Y	N	N	Y
		0.63	Y	Y	Y	Y	Y	Y
		0.73	Y	Y	Y	Y	Y	Y
SG75	All	0.48	N	N	N	N	N	N
		0.58	Y	Y	Y	Y	Y	Y
		0.68	Y	Y	Y	Y	Y	Y
SE	All	0.87	N	Y	Y	N	N	Y
		0.93	Y	Y	Y	N	N	Y
IG[6]	All	0.80	Y	Y	Y			
IE	All	0.93	Y	Y				
HP	1,14	1.80	Y	Y	Y	N	Y	Y
		2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	2-5,12	1.80	Y	Y	Y	Y	Y	Y
		2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	6-11 &	1.80	Y	Y	Y	N	Y	Y
	13, 15	2.20	Y	Y	Y	Y	Y	Y
		2.60	Y	Y	Y	Y	Y	Y
HP	16	1.80	N	N	N	N	N	N
		2.20	N	Y	N	N	N	N
		2.60	Y	Y	Y	N	N	Y

Table 3-18 – Reference Notes for Complying Water Heating Systems[1]

NOTES:

1. The water-heating systems listed here have been pre-calculated to determine compliance with the water-heating budgets (see Note 4). See Chapter 6 for the complete method, including definitions and installation criteria for all system components. NOTE: All storage tank water heaters with less than 0.58 energy factor are assumed to have R-12 external tank insulation. This insulation is a mandatory requirement for storage tank water heaters with an energy factor between 0.53 and 0.579.
2. Water heater types: SG50 = Storage gas, 50 gallons or less; SG75 = Storage gas, 51 to 75 gallons, less than 75,000 Btu/hr input; HP = Heat Pump, 50 gallons or less; IG = Instantaneous Gas, pilot loss may not exceed 600 Btu/hr; SE = Storage electric, 50 gallons or less. Note that compliance of heat pump water heaters varies by climate zone.
3. Distribution Systems: STD = Standard; HWR = Hot water recovery; POU = Point of use; Pipe Insul = Pipe insulation credit; Recirculation: NoCtrl = Recirculation system with no controls; Temp/Timer = Recirculation system with either temperature or timer controls; Demand/Temp = Recirculation system with either demand controls, or with a combination time/temperature control. Pipe insulation is required on the entire length of recirculating piping, except when equipped with demand control. For systems with parallel piping, use the water heating forms to determine if the system meets the water-heating budget. See Chapter 6 for installation criteria and definitions.
4. Water-heater systems listed with a "Y" meet the water-heating budget and must be installed with the applicable efficiency and distribution devices used to receive credits. Water heater systems listed with an "N" do not meet standard water-heating budget.
5. Solar credit requires 50% solar contribution. See Chapter 6.
6. For instantaneous gas water heaters (IG), the value listed in the Energy Factor column is the Recovery Efficiency (RE).

Install:

- Equipment type as specified on the CF-1R

- Equipment efficiency as specified on the CF-1R
- Distribution type specified on the CF-1R
- Pipe insulation:
  - R-4 on the first 5 feet hot and cold for nonrecirculating systems with pipe diameters of 2 inches or less, R-6 for pipe diameters greater than 2 inches.
  - Entire length of recirculating piping (mandatory except when equipped with demand control)
  - If “pipe insulation” is indicated, it was used for credit and the entire length of hot water piping must be insulated to R-4 (R-6 if pipe > 2”)

The builder should complete:

- Installation Certificate (CF-6R) for installed equipment.

The field inspector should check the CF-1R for required measures and the CF-6R for installation information.

3.8 Compliance Documentation

Documentation of the prescriptive compliance approach is simple. In many cases, the only requirement is to complete a residential Certificate of Compliance (CF-1R) form, as well as submit a Mandatory Measures Checklist (MF-1R).

On the CF-1R form, the climate zone and package selected for compliance should be specified. The building features and devices that must be installed to meet the package requirements are also indicated.

A Form 3R is required to document equivalent assembly R-values if the proposed R-value is not the same or higher than the R-value listed in the package.

Form S, Solar Heat Gain Coefficient (SHGC) Worksheet, is required to document fenestration and exterior shading combinations. When a fenestration product has an SHGC equal or lower to that required by the package, Form S is not required. Only exterior devices and SHGCs from Table 3-10 may be used in SHGC combination calculations for Form S.

4 Compliance Through Quality Construction

The *Standards* require quality design and construction of HVAC systems and air distribution systems. They also offer compliance credit for the construction of less leaky building envelopes. With the 2001 *Standards*, testing of ducts, refrigerant charge, and airflow was added to the prescriptive requirements (Package D) and is assumed as part of the standard design in performance calculations. Many of the compliance credit options require installer diagnostic testing and certification, and independent diagnostic testing and field verification by a certified Home Energy Rater. This chapter is organized in the following sections.

- Duct Efficiency
- Infiltration & Ventilation
- Refrigerant Charge and Air Flow Testing
- Diagnostics and Field Verification
- Procedures for HVAC System Design and Installation

4.1 Duct Efficiency

4.1.1 Overview

HVAC duct efficiency is a very important feature in energy efficient buildings. The prescriptive requirements require that ducts be sealed and tested in all climates. This requirement was added with the 2001 *Standards*; previously it was a compliance option. Duct efficiency is impacted by the following parameters

1. Duct location (attic, crawlspace, basement, inside conditioned space, or other).
2. Condition of the unconditioned space, e.g., does the attic have radiant barriers
3. Duct insulation
4. Duct surface area
5. Air leakage of the duct system
6. Design of the duct system to ACCA Manual D

In performance calculations, duct efficiency can be calculated in one of two ways: (1) default input assumptions or (2) diagnostic measurement values (see also Section 4.4). The computer program will use default assumptions for the proposed design when the user does not intend to make improvements in duct efficiency. For low-rise residential buildings there is a compliance penalty if the ducts are not sealed and tested.

Methods for conducting diagnostic testing and field verification for duct efficiency improvements are described in detail in *Appendix F* of the *Alternative Calculation Method Approval Manual,* which is repeated in the *Residential Energy Conservation Manual* as Appendix J.

Also, the duct connections and leaks shall not be sealed with cloth back rubber adhesive tapes (i.e., duct tapes) unless such tape is used in combination with mastic and draw-bands. This requirement must be specified in the HERS Required Verification listings on the CF-1R and the CF-4R.

When more than one HVAC system serves the building or dwelling, the duct efficiency is determined for each system based on the improvements made to each duct system, and a conditioned floor area-weighted average of the efficiencies of each separate system is determined.

4.1.2 Duct Location

The location of ducts has a significant effect on the efficiency of distributing heated or cooled air. Therefore, the location of ducts affects the way the program models the overall efficiency of space conditioning equipment. Ducts are typically installed in attics. This is the location that results in the greatest energy loss. This is the default location for compliance purposes. Ducts located in crawlspaces, basements or in conditioned space can be significantly more efficient and may require HERS rater verification as discussed below. Ducts in other spaces (i.e., not in crawlspaces, basements or in conditioned space; e.g., in garages) are assumed to perform the same as ducts in attics. When compliance credit is taken for improved duct location, the installer must certify on the CF-6R that the ducts are installed in that location.

A default compliance credit for ducts located in crawlspaces or basements may be approved by the local enforcement agency without HERS rater verification. The default assumptions for ducts installed in crawlspaces or basements apply only to buildings with all supply ducts installed in the crawlspace or basement. A duct layout must be included in the plans that show that all of the supply registers are located in the floor. If any story of a building has any supply registers located more than two feet above the floor, the duct location for that story must be modeled as 100% in the attic. The computer program will automatically specify that all supply registers for each story are located in the floor in the *Special Features and Modeling Assumptions* listing to aid the local enforcement agency's inspections.

Compliance credit for ducts in locations other than attics is also available by using the diagnostic duct surface area alternative. This alternative requires HERS rater verification. In this alternative, compliance can be determined by specifying the duct surface area in each location in which the supply ducts are to be installed. With this method, there must be an *ACCA Manual D Design* identifying the duct locations, sizes and airflow to each room as described in Section 4.1.8, and the HERS rater must verify the *ACCA Manual D Design* (which includes airflow to each room) and that the installation matches the design for duct sizes, lengths and surface areas in each location as specified in Section 4.1.6. When using this diagnostic surface area alternative for ducts in crawlspaces (or other locations), there are no limitations on the locations of individual registers as long as they match the design.

The distribution of duct surface areas by location must appear on the *HERS Required Verification* list of a compliance computer program output for verification by an approved HERS rater.

4.1.3 Ducts Inside Conditioned Space

Credit is given when most or all of the ducts of a ducted HVAC system are installed inside conditioned space. Credit can be taken for ducts inside the conditioned space for two situations: 1) Less than 12 lineal feet of ducts within unconditioned space; and 2) all ducts (and the air handler) within the conditioned space. The first situation would typically apply to a ducted furnace or heat pump inside a garage with a relatively short duct run from the air handler to the conditioned space.

Compliance credit can also be taken for duct systems where all ducts including the air handler are installed inside conditioned space. Ducted, central gas furnaces installed in this manner will need to have provisions for supplying outdoor air for combustion and combustion product venting without using draft relief openings. These ducts in conditioned space options must be specified on the *HERS Required Verification* list for verification by an approved HERS rater.

Non-central gas furnaces [those listed in Table G-1 of Appendix G in this *Manual*] such as wall furnaces are compared to a *Standard Design* using a non-central gas furnace with no ducts and the minimum allowed efficiency for the type of furnace used in the *Proposed Design*. Similarly, non-central air conditioners [those listed in Table G-3B of Appendix G of this *Manual*] are compared to a similar non-central air conditioner without ducts in the *Standard Design*. Other systems, such as hydronic heating systems with a central heater or boiler and multiple terminal units, are considered central HVAC systems that are compared to a ducted system in the *Standard Design*. Since the hydronic system has no ducts, there is a significant energy credit through the performance method.

4.1.4 Ducts in Attics with Radiant Barriers

Installation of a radiant barrier in the attic increases the duct efficiency by lowering attic summer temperatures. Compliance credit for radiant barriers requires listing of the radiant barrier in the *Special Features and Modeling Assumptions* listings to aid the local enforcement agency's inspections. Compliance credit for a radiant barrier does not require HERS rater verification.

4.1.5 Duct Insulation

The R-value of duct insulation is specified for ducts in unconditioned space. R-4.2 is a mandatory feature and is the default R-value. Compliance credit can be taken for additional duct insulation. If ducts with multiple R-values are installed, the lowest duct R-value shall be used for the entire duct system. In some cases the space on top of the duct boot is limited and cannot be inspected. For this reason, the insulation R-value within two feet of the boot may be excluded from the determination of the overall system R-value. When the modeled R-value is greater than 4.2, the computer program must report the specified R-value in the *Special Features and Modeling* Assumptions listing to aid the local enforcement agency's inspections. Compliance credit for Increased duct insulation does not require HERS rater verification.

4.1.6 Duct Surface Area

The default values for duct surface areas outside of conditioned space are 27% of conditioned floor area (CFA) for supply duct surface area; 5% of CFA for return duct surface area in single story dwellings and 10% of CFA for return duct surface area in dwellings with two or more stories. Compliance credit can be taken for proposed designs with reduced duct surface areas outside of conditioned space. The proposed design can specify field measured reduced supply duct surface area. If compliance credit is taken for reduced supply surface area, the installer must certify the installed surface area on the CF-6R. Duct surface area shall be calculated from measured duct lengths and nominal diameters to the outside of the duct insulation (for round ducts) or perimeters of the outside of the duct insulation (for rectangular ducts) of each duct run in the building.

Reduced duct surface areas must be shown to preserve adequate airflow to receive duct efficiency credit. Consequently, compliance credit for measured reduced duct surface area can only be taken in conjunction with ducts that are designed to conform to ACCA manual D (including duct layout and design specifications on the plans). The total specified measured surface area and its subcomponent allocation by duct location must be in the *HERS Required Verification* listing, and be verified by a certified HERS rater. Credit for measured reduced duct surface area also requires that the HERS rater verify the consistency of the actual duct system with the ACCA Manual D design as specified in Section 4.1.8 below.

4.1.7 Duct Leakage

Prescriptive Packages C and D require that ducts be diagnostically tested to have a leakage of 6% of fan airflow or less. This is a prescriptive requirement that can be traded off only in performance calculations. If duct sealing and diagnostic testing is not planned in performance calculations, then a leakage of 22% of fan airflow must be used in the calculations for the proposed design.

The target duct leakage is determined as a percentage of the fan airflow. Fan airflow is determined as described below.

Determining Fan Airflow

With either of the above methods, it is necessary to determine the fan airflow before the leakage can be calculated. Fan airflow can be determined using one of four methods described below:

1. Fan airflow can be based on the cooling capacity of the equipment. With this method the fan airflow is assumed to be 400 cfm/ton times the capacity of the equipment in tons. This is the most common and easiest method to determine fan flow.
2. Fan airflow can be based on the heating capacity of the equipment. In this case the fan airflow is assumed to be 21.7 cfm/(kBtu/h) times the capacity of the heating equipment in thousands of Btu/h. This method is typically used for heating only systems.
3. The fan airflow can be based on floor area. For climates 8 through 15, fan airflow can be assumed to be 0.7 cfm/ft^2 times the floor area served by the system. For climates 1 through 7 and 16, the fan airflow can be assumed to be 0.5 cfm/ft^2 times the floor area served. This is the default method used by the approved computer methods.
4. The fan airflow can be measured in the field (see Appendix J for measurement procedures).

In addition to installer leakage testing and certification, the prescriptive requirement for duct sealing requires diagnostic testing and verification by a certified HERS rater. The *HERS Required Verification* listing and the CF-6R must specify the target duct leakage(s) for verification by the HERS rater.

4.1.8 ACCA Manual D Design – Duct Layout and System Fan Flow

The default condition assumes that the duct system has not been designed to meet ACCA manual D. Compliance credit can be taken if the duct system is designed to meet ACCA manual D, and a duct layout showing locations and sizes of ducts and placement of registers, engineering calculations, and duct system specifications are in the plans. The plans must specify either the system fan flow determined by the ACCA manual D design or the installation of a thermostatic expansion valve. The installation of a thermostatic expansion valve must be verifiable through installation of a removable access panel on the cooling coil. The ACCA Manual D design calculations must be submitted with the permit application along with the plans and energy calculations. This submittal does not need to include the specific ACCA Manual D calculation forms, but must include the same information in a format similar to that used in the ACCA Manual D forms so that a reviewer using ACCA Manual D can readily identify the calculations match those identified in ACCA Manual D.

Compliance credit for ACCA manual D design requires diagnostic testing and verification by an approved HERS rater. The system fan flow or the installation of a thermostatic expansion valve must be specified on the *HERS Required Verification* listing. The HERS rater must verify the existence of the ACCA manual D design, specifications and layout, and verify the consistency of the actual HVAC distribution system with the design. This consistency check includes verifying that space-by-space load and supply air calculations were done for each space, that duct runs are no longer than the design, that the ducts are not compressed or constricted, and that duct sizes and insulation R-values match the design. The HERS rater also must either 1) diagnostically test the system fan flow and verify that the fan flow specified by the ACCA manual D design is achieved or 2) remove the access panel and verify the installation of the thermostatic expansion valve.

4.2 Infiltration & Ventilation

4.2.1 Overview

Infiltration is the unintentional replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. This is a major component of heating and cooling loads. Ventilation is the intentional replacement of conditioned air with unconditioned air through opening windows or mechanical ventilation. Credit is offered through compliance methods for options that reduce building envelope air leakage.

Ventilation in residential buildings is typically achieved by opening windows either to provide natural ventilation for cooling purposes or to reduce stuffiness or odors. The use of continuous mechanical ventilation provides a greater degree of control of the rate of exchange of conditioned and unconditioned air. Continuous mechanical ventilation can be provided through either supply fans or exhaust fans. Providing **supply** fan ventilation is also a means to avoid building depressurization, which otherwise can lead to backdrafting of combustion appliances in “unusually tight” buildings.

Reduction in building envelope air leakage reduces infiltration and can result in significant energy savings especially in climates with more severe winter and summer conditions. It also can result in improved building comfort, reduced moisture intrusion, and can avoid introduction of air pollutants due to leakage from garages or attics.

4.2.2 Indoor Air Quality

ASHRAE Standard 62 *Ventilation for Acceptable Indoor Air Quality* specifies a minimum effective annual air exchange rate. This minimum rate is the combination of infiltration, ventilation through window opening and continuous mechanical ventilation if supplied. For typical California homes infiltration is excessive and the ASHRAE 62 standard is met or exceeded with occasional window opening. As building envelope leakage is reduced, the frequency for when windows need to be opened slightly to relieve stuffiness, remove odors and provide indoor air quality increases.

4.2.3 Optimal Building Envelope Leakage

From an energy standpoint there is an optimal level of reduced building envelope air leakage if additional ventilation is provided through opening windows alone. Below that optimal building envelope air leakage, the energy penalty of increased frequency of window opening exceeds the energy savings of the reduction in infiltration. If building envelope leakage is reduced substantially below the optimal energy savings level, a level that the Commission considers to be “unusually tight” per the California Mechanical Code can be reached where it is necessary to provide continuous mechanical supply ventilation.

4.2.4 Algorithms

Algorithms approved by the Commission keep track of the combination of infiltration, ventilation through opening windows, and continuous mechanical ventilation, if any, to model conformance with the ASHRAE 62 standard and determine the energy consequences. Approved computer programs can be used to determine optimal building envelope leakage levels that can be specified for compliance purposes.

Approved computer programs use a default building envelope air leakage (expressed in terms of Specific Leakage Area, SLA) for proposed designs when the user does not intend to take compliance credit for building envelope sealing. The default is set at 4.9 SLA. Careful attention to building envelope sealing would result in significantly lower SLA levels.

4.2.5 Blower Door Testing

Compliance credit can be taken for reduced building envelope leakage verified through diagnostic blowerdoor testing as specified by ASTM E-779-87, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. Users of approved computer programs can determine the compliance credit available for Specific Leakage Area (SLA) levels (or target blowerdoor test results). The program will automatically convert that SLA level to the target $cfm50_H$ required for the blowerdoor testing to achieve the modeled SLA, and specify that target $cfm50_H$ level in the *HERS Required Verification* listing on the CF-1R and C-2R. The installer must do testing to demonstrate that building envelope leakage has been reduced to the target $cfm50_H$ level or lower, and document the blowerdoor test results on the CF-6R. An approved HERS rater must do blowerdoor testing to verify that the target $cfm50_H$ has been achieved (see Section 4.4 for Diagnostics and Field Verification procedures and requirements). Installers and HERS raters should be aware of minimum cfm requirements described in 4.2.6.

4.2.6 Mechanical Supply Ventilation Requirements for Unusually Tight Buildings

Compliance software will report in the *HERS Required Verification* section the minimum allowed $cfm50_H$ (corresponding to an SLA of 1.5) unless continuous mechanical **supply** ventilation is installed. This minimum allowed value without continuous mechanical supply ventilation is considered by the Commission to be “unusually tight” per the requirements of the California Mechanical Code.

The *HERS Required Verification* section of the CF-1R must state that when the minimum blowerdoor testing reveals that the $cfm50_H$ is less than the minimum allowed value, corrective action must be taken either to intentionally increase the infiltration or provide for continuous mechanical **supply** ventilation adequate to maintain the residence at a pressure greater than -5 Pascal relative to the outside air pressure with other continuous ventilation fans operating. Blowerdoor testing must be done by both the installer and the HERS rater to verify compliance with these requirements.

The total power consumption of the continuous supply ventilation fans and continuous exhaust fans are required inputs when compliance credit is taken for reduced building envelope leakage and mechanical ventilation is installed.

4.2.7 Mechanical Ventilation Requirements for Low Leakage Designs

When the user of compliance programs chooses the proposed design envelope leakage to be below 3.0 SLA, continuous mechanical ventilation (either exhaust or supply ventilation) must be installed. Whenever continuous mechanical ventilation is installed, a minimum capacity of 0.047 cfm per square foot of conditioned floor area is required. This requirement for installation of continuous mechanical ventilation is reported automatically by the program in the *HERS Required Verification* section of the CF-1R and C-2R. The installer and the HERS rater must confirm compliance with these requirements.

When reduced building envelope leakage or continuous mechanical ventilation is specified for compliance, the computer program will automatically include in the *Special Features and Modeling Assumptions* section a statement that the homeowner's manual provided by the builder to the homeowner must include instructions that describe how to use the operable windows or continuous mechanical ventilation for proper ventilation.

The total power consumption of the continuous supply ventilation fans and continuous exhaust fans are required inputs when compliance credit is taken for reduced building envelope leakage and mechanical ventilation is installed.

4.2.8 Envelope Leakage Credit for Reduced Duct Leakage

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special "default" compliance credit can be taken for building envelope leakage reduction resulting from reduced duct leakage. To qualify for this credit all requirements for reduced duct leakage described in Section 4.4, including diagnostic testing, must be met. A "default" reduction in Specific Leakage Area of 0.50 is allowed for this credit.

4.2.9 Air Retarding Wrap Credit

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special "default" compliance credit can be taken for building envelope leakage reduction resulting from installation of an air retarding wrap (i.e., housewrap). To qualify for the "default" compliance credit, an air retarding wrap must be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building* Walls, and have a minimum perm rating of 10. Insulating sheathing and building paper do not qualify as air retarding wraps.

The air-retarding wrap must be installed per the manufacturer's specifications that must be provided to comply with ASTM E1677-95. In particular, the air-retarding wrap must meet the following installation requirements:

- The air retarding wrap must be applied continuously
- All tears or breaks must be repaired with manufacturer approved tape
- All horizontal seams must be lapped in a shingle-like manner and taped.
- All vertical seams must be lapped.
- All windows and penetrations must be taped or caulked
- The air-retarding wrap must be taped or otherwise sealed at the slab junction

When compliance credit is taken for an air-retarding wrap, the computer program will automatically include the air retarding wrap and the above specifications in the *Special Features and Modeling* Assumptions section of the CF-1R and C-2R to facilitate inspection by the local enforcement agency. Compliance credit for an air-retarding wrap does not require HERS rater verification.

Compliance credit is provided for a “default” reduction in Specific Leakage Area of 0.50.

4.2.10 Reduced Duct Leakage in Combination with Air Retarding Wrap

The default credits in Sections 4.2.8 and 4.2.9 may be added when both measures are installed and the criteria in Sections 4.2.8 and 4.2.9 are both met.

4.3 Refrigerant Charge and Air Flow Testing

This section describes the procedures for verifying that split system air conditioners have the correct refrigerant charge and that they have adequate airflow across the cooling coils. The prescriptive requirements require this testing if the air conditioner does not have a thermostatic expansion valve (TXV). Appendix L of this *Manual* (also Appendix K of the Residential ACM Approval Manual) describes the procedures in detail, and refrigeration technicians who do the testing should refer to these and other more technical documents. This section is just a summary intended for those who need to know about the procedures but will not be doing the testing.

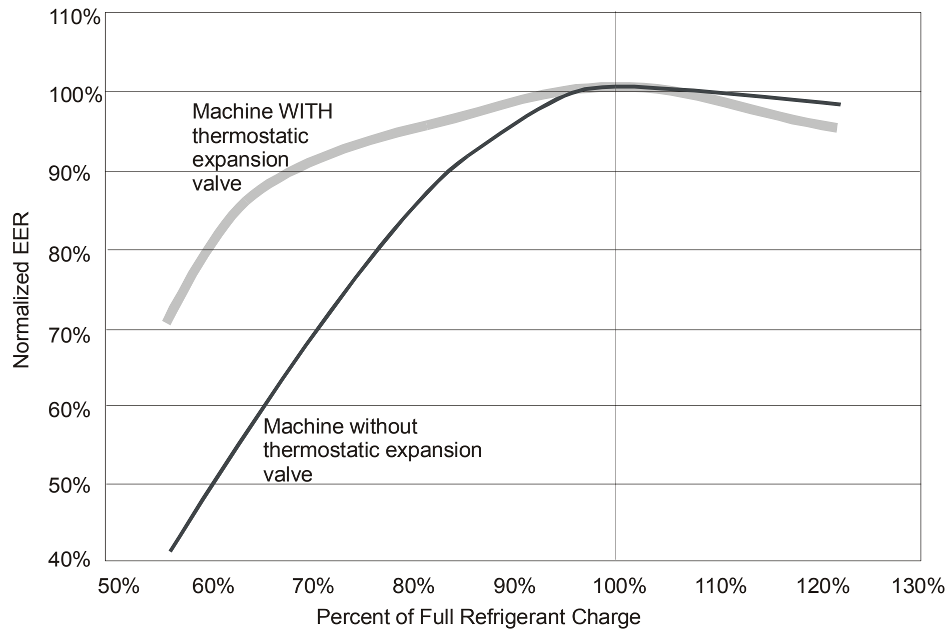
4.3.1 Overview

A residential air conditioner is a complicated piece of equipment, and like an automobile, it must be tuned in order to achieve maximum performance and the best energy efficiency. Two important factors are the amount of refrigerant in the system (the charge) and the airflow rate across the evaporator (the cooling coil near the fan). Air conditioner energy efficiency suffers if the refrigerant charge is too low or if the airflow across the coil is not adequate. In addition to a loss of efficiency, excessive refrigerant charge can lead to premature compressor failure while insufficient charge can cause compressors to overheat. Low airflows can lead to ice buildup on the cooling coil and lead to compressor failure. High airflow is not generally a problem.

To help avoid these problems the prescriptive standards require that systems be correctly installed. This section describes the measurements and tests required to verify proper installation. The testing requirement applies only to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs). If a TXV is installed, refrigerant charge and airflow testing are not necessary. Nor does the testing requirement apply to packaged systems, where the refrigerant charge is verified in the factory. The testing must occur after the HVAC installer has installed and charged the system in accordance with the manufacturer’s specifications. For homes with multiple systems, each system must be tested separately.

Figure 4-1 shows how a thermostatic expansion valve can help mitigate the efficiency penalty of a system with too little refrigerant (under charged). As long as the machine has the correct charge (100%), the TXV has no benefit. However, for systems that are undercharged, the efficiency falls off less rapidly if a TXV is installed.

Figure 4-1– Benefit of Thermostatic Expansion Valve



Two procedures are described here for testing refrigerant charge and airflow. The first procedure, the Standard Charge and Airflow Measurement procedure (Section 4.3.2), may be done by a HERS rater and applies only when the outdoor temperature is above 55 ºF. The second procedure, the Alternate Charge and Airflow Measurement procedure (Section 4.3.3), must be performed by a refrigeration technician and must be used when the outdoor temperature is below 55 °F.

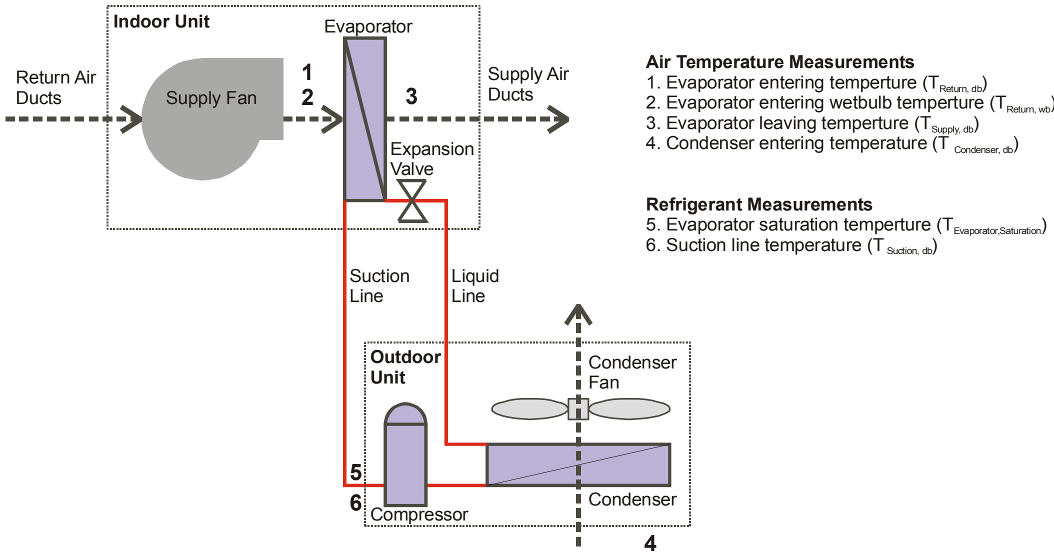
4.3.2 Standard Charge and Airflow Measurement Procedure

The first step is to turn on the air conditioning system and let it run for at least 15 minutes in order to stabilize temperatures and pressures. While the system is warming up and stabilizing, the HERS rater or the installer may fit the instruments needed to take the measurements.

Air temperatures are measured just before the air enters the cooling coil. For typical blow-through systems the measurement will be made in the fan cabinet between the fan and the coil. At this location (see points 1 and 2 in Figure 4-2), both the drybulb and wetbulb temperatures are measured. The air temperature is also measured in the supply duct, just down stream of the cooling coil (see point 3 in Figure 4-2). Finally the air temperature is measured where the air enters the outdoor condensing coil (see point 4 in Figure 4-2). It is important that the outdoor temperature sensor be shaded from direct sun.

In addition to the air temperature measurements, the HERS rater also takes two measurements for the refrigerant. Both of these measurements are taken near the suction line service valve near the compressor (see points 5 and 6 in Figure 4-2). The first measurement is the temperature of the refrigerant, which is taken by attaching a thermocouple to the outside of the refrigerant line. The second measurement is the saturation temperature of the refrigerant. The saturation temperature requires a special instrument called a refrigerant gauge that is installed to the suction line service valve (the inlet to the compressor). The saturation temperature is equivalent to measuring the saturation pressure, since there is a one-to-one relationship between the saturation temperature and the saturation pressure.

Figure 4-2– Measurement Locations for Refrigerant Charge and Airflow Tests



Once the temperatures are measured, the *Superheat Charging Method* is used to determine if the refrigerant charge is acceptable and the *Temperature Split Method* is used to determine if airflow across the evaporator coil is acceptable. The procedure may only be used when the outdoor temperature is 55°F or higher and after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. The test must be performed by a certified HERS rater. The procedure requires properly calibrated digital thermometers, thermocouples, and a refrigerant gauge.

Superheat Charging Method

The *Superheat Charging Method* involves comparing the measured superheat to a reference value from a table. The measured superheat is the difference between the temperature of the refrigerant ($T_{Suction,\ db}$) and the saturation temperature of the refrigerant ($T_{Evaporator,\ Saturation}$). The reference superheat is read from a table (see Table L-1 in Appendix L). For illustration purposes, the structure of the table is shown below as Table 4-1.

If the difference between the actual and target superheat is between minus 5 ºF and plus 5°F, then the system passes the required refrigerant charge criteria. If the difference is greater than plus 5°F, then the system is undercharged and the installer shall add refrigerant and repeat the measurement procedure. If the difference is between –5 and -100°F, then the system is overcharged and it is necessary for the installer to remove refrigerant and repeat the measurement procedure. Only an EPA certified technician may add or remove refrigerant.

Table 4-1 – Structure of Target Superheat Temperature Table

Complete table is in Appendix L

Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	Return Air Wet-Bulb Temperature (°F) ($T_{Return, wb}$)									
	50	51	52	53	54	55	..	..	75	76
55										
56										
57										
..	Target Superheat Temperatures = (Suction Line Temperature minus Evaporator Saturation Temperature) – See Appendix L									
..										
93										
94										
95										

The Temperature Split Method

With the *Temperature Split Method,* the air temperature drop across the cooling coil is compared to a reference value read from a table. This temperature drop is called the temperature split, thus the name. The actual temperature split is the difference between the drybulb temperature in the return (entering the evaporator) and the drybulb temperature in the supply (leaving the evaporator). See the equation below.

Equation 4-1

$$\text{Actual Temperature Split} = T_{Return,\ db} - T_{Supply,\ db}$$

The Target Temperature Split depends on return air wet-bulb temperature ($T_{Return,\ wb}$) and return air dry-bulb temperature ($T_{Return,\ db}$). Table 4-2 shows the organization of the table. Appendix L has the full tables. If the difference between the actual and target is within plus 3°F and minus 3°F, then the system passes the airflow test.

If the difference is greater than plus 3°F, then airflow is inadequate and must be increased. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After the installer corrects the problem and verifies adequate airflow through the installers own testing, the HERS rater repeats the measurements to verify a correct refrigerant charge and airflow. The rater and/or the installer should allow system to stabilize for 15 minutes before performing the measurements.

If the difference is between minus 3 °F and minus 25 °F, the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow. If the re-measured difference is still out of range, then (between minus 3 °F and minus 25 °F), the system passes, but it is likely that the air conditioner is not producing the capacity it was designed to produce. There may be problems with this air conditioner. (It is possible, but unlikely, that airflow is higher than average.)

Table 4-2 – Structure of Target Temperature Split (Return Dry-Bulb minus Supply Dry-Bulb) Table

Complete table is in Appendix L

Return Air Dry–Bulb (°F) (T return, db)	Return Air Wet-Bulb Temperature (°F) ($T_{Return, wb}$)									
	50	51	52	53	54	55	..	..	75	76
70										
71										
72										
..	Target Temperature Splits = (Return Dry Bulb Temperature minus Supply Dry Bulb Temperature) – See Appendix L									
..										
82										
83										
84										

4.3.3 Alternate Charge and Airflow Measurement Procedure

This section describes the Alternate Charge and Airflow Measurement Procedure. With this method, the required refrigerant charge is calculated using the *Weigh-In Charging Method* and adequate airflow across the evaporator coil is calculated using the *Measured Airflow Method*. This method is used when the outdoor temperature is below 55°F. EPA certified technicians, not HERS raters, must perform the procedure. The technician that performs this procedure must be able to do the following:

- Transfer and recover refrigerant
- Accurately weigh the amount of refrigerant added or removed using an electronic scale
- Calculate the refrigerant charge adjustment needed to compensate for non-standard dimensions in the suction line or liquid line

The airflow across the indoor evaporator coil shall be measured using one of the two methods described in Appendix J:

- Section 4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood
- Section 4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching

The measured airflow method is compared to see that it is above the required minimum of 385 cfm per nominal ton of capacity (assuming coil is dry). The following steps describe the calculations using the measurement procedure described in Appendix J.

1. Record the measured air flow (cfm measured) obtained from the measurement procedures described in Appendix J of the Residential Manual.
2. Obtain and record the rated cooling capacity ($C_{cooling}$) in Btu/h.
3. Calculate the minimum airflow in cfm as $C_{cooling}$ X 0.032.
4. If the measured airflow is greater than the required airflow, then the system passes the adequate airflow criteria. If the measured airflow is less than the required airflow, the system does not pass the adequate airflow criteria.

4.4 Diagnostics and Field Verification

This section describes the procedures for special verification of energy efficiency measures and for diagnostic testing of air distribution ducts, building envelope leakage, refrigerant charge and airflow by a certified HERS rater. Diagnostic testing and/or field verification by a HERS rater is often required to show compliance with both the prescriptive and performance compliance methods. However, field verification and testing is only required when measures or equipment are installed which require field verification and/or testing, as specified in Section 4.4.2. If these types of measures or equipment are not installed, then field verification and testing is not required. For example, if there are no air distribution ducts (no new ducts for additions), then no testing of ducts is required. Similarly, if there is no split system air conditioner or heat pump, then it is not necessary to diagnostically test the refrigerant charge and airflow. See “When a HERS Rater is Not Needed” in Section 3.1 for a discussion of testing and verification requirements with the prescriptive standards. See sections 5.4.6, 5.4.8 and 5.4.9 for a discussion of testing and verification requirements with the performance approach.

4.4.1 California Home Energy Rating Systems

The Commission is required to regulate home energy rating system (HERS) providers in California. These regulations appear in the California Code of Regulations, Title 20, Chapter 4, Article 8, Sections 1670-1675. Approved HERS providers are authorized to certify raters and maintain quality control over ratings. Ratings are based on visual inspection and diagnostic testing of the physical characteristics and energy efficiency features of dwelling units, as constructed. When the term “dwelling unit” is used in reference to Home Energy Rating Systems (HERS) Required Verification and Diagnostic Testing applied to multifamily buildings, it shall mean each dwelling unit within each multifamily building project. When the term “building owner” is used in this Chapter, it shall mean owner of the dwelling unit.

When compliance documentation indicates field verification and diagnostic testing of specific energy efficiency measures as a condition for complying with Title 24, an approved HERS provider and certified HERS rater shall be used to conduct the field verification and diagnostic testing. HERS providers and raters shall be considered special inspectors by building departments, and shall demonstrate competence, to the satisfaction of the building official, for the visual inspections and diagnostic testing. The HERS provider and rater shall be independent entities from the builder or subcontractor installer of the energy efficiency improvements being tested and verified, and shall have no financial interest in the installation of the improvements. HERS raters cannot be employees of the builder or contractor whose work they are verifying. Also HERS raters cannot have financial interest in the builder’s or contractor’s business or advocate or recommend the use of any product or service that they are verifying.

Example 4-1 – HERS Rater Conflict of Interest

Question

I heard that there are conflict-of-interest requirements that HERS raters must abide by when doing field verification and diagnostic testing. What are these requirements?

Answer

HERS raters are expected to be objective, independent, third parties when they are fulfilling their duties as field verifiers and diagnostic testers. In this role they are serving as special inspectors for local building departments. By law HERS raters must be independent entities from the builder or subcontractor installer of the energy efficiency features being tested and verified. They can have no financial interest in the installation of the improvements. HERS raters can not be employees of the builder or subcontractor whose work they are verifying. Also, HERS raters can not have financial interest in the builder’s or contractor’s business or advocate or recommend the use of any product or service that they are verifying. Section 106.3.5 of the California Building Code prohibits a special inspector from being employed (by contract or other means) by the contractor who performed the work that is being inspected.

The Commission expects HERS raters to enter into a contract with the builder (not with sub-contractors) to provide independent, third party diagnostic testing and field verification, and the procedures adopted by the Commission call for direct reporting of results to the builder, the HERS provider and the building official. Although the Commission does not recommend it, a “three party contract” with the builder is possible, provided that the contract delineates both the independent responsibilities of the HERS rater and the responsibilities of a sub-contractor to take corrective action in response to deficiencies that are found by the HERS rater. Such a “three party contract” may also establish a role for a sub-contractor to serve as contract administrator for the contract, including scheduling the HERS rater, invoicing and payment provided the contract ensures that monies paid by the builder to the HERS rater can be traced through audit. It is critical that such a “three party contract” preserves rater independence in carrying out the responsibilities specified in Commission adopted field verification procedures. Even though such a “three party contract” is not on its face in violation of the requirements of the Commission, the closer the working relationship between the HERS rater and the sub-contractor whose work is being inspected, the greater the potential for compromising the independence of the HERS rater.

The California Home Energy Efficiency Rating System (CHEERS) has been approved by the Commission to serve as the HERS provider to certify and oversee HERS raters throughout the State. CHEERS is required to provide ongoing monitoring of the propriety and accuracy of HERS raters in the performance of their duties and to respond to complaints about HERS rater performance. In cases where there may be real or perceived compromising of HERS rater independence, CHEERS is responsible for providing increased scrutiny of the HERS rater, and taking action to ensure objective, accurate reporting of diagnostic testing and field verification results, in compliance with Commission adopted procedures.

Building officials have authority to require HERS raters to demonstrate competence, to the satisfaction of the building official. Building officials should place extra scrutiny on situations where there may be either real or perceived compromising of the independence of the HERS rater, and exercise their authority to disallow a particular HERS rater from being used in their jurisdiction or disallow HERS rater practices that the building official believes will result in compromising of HERS rater independence.

4.4.2 HERS Required Verification and Diagnostic Testing

HERS diagnostic testing and field verification is required for:

- Duct air sealing,
- ACCA Manual D design and installation,
- Refrigerant charge and airflow measurement, and
- Building envelope sealing beyond improvements covered by default assumptions,

HERS field verification is required for:

- Thermostatic expansion valves,
- Duct surface area reductions, and
- Duct location improvements beyond those covered by default assumptions.

These features shall be listed as *HERS Verification Required* features on the *Certificate of Compliance* (CF-1R) and the *Computer Method Summary* (C-2R). Such verification constitutes “eligibility and installation criteria” for these features. Field verified and diagnostically tested features must be described in the *Compliance Supplement*.

4.4.3 Installation Certification

When compliance includes duct sealing, ACCA Manual D design and installation, refrigerant charge and airflow measurement or envelope sealing, builder employees or subcontractors shall:

- Complete diagnostic testing, and
- Certify on the CF-6R the diagnostic test results and that the work meets the requirements for compliance credit.

For refrigerant charge and airflow measurement when the outside temperature is below 55°F, the installer shall follow the alternate charge and airflow measurement procedure described in Appendix L, Section 3. Builder employees or subcontractors using these procedures shall certify on the CF-6R that they used these procedures, the diagnostic results, that the work meets the requirements for compliance credit, and that they will return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

For duct sealing completed at the rough-in stage of construction using aerosol sealant closures, builder employees or subcontractors shall:

- At rough-in, complete the fan pressurization test and certify on the CF-6R the diagnostic results,
- After installation of the interior finishing wall, verify sealing of the ducts using either the house pressure test or the pressure pan test or by visual inspection of all duct connections (including duct to air handler connections), and
- Certify on the CF-6R the diagnostic results and that the work meets the requirements for compliance credit.

When compliance includes a thermostatic expansion valve, duct surface area reductions and duct location improvements beyond those covered by default assumptions, builder employees or subcontractors shall:

- Record the feature on the CF-6R,
- Record on the CF-6R the duct surface area in each duct location, and
- Certify on the CF-6R that the duct surface area and locations match those on the plans, and that the work meets the requirements for compliance credit.

Installation certifications are required for each and every dwelling unit.

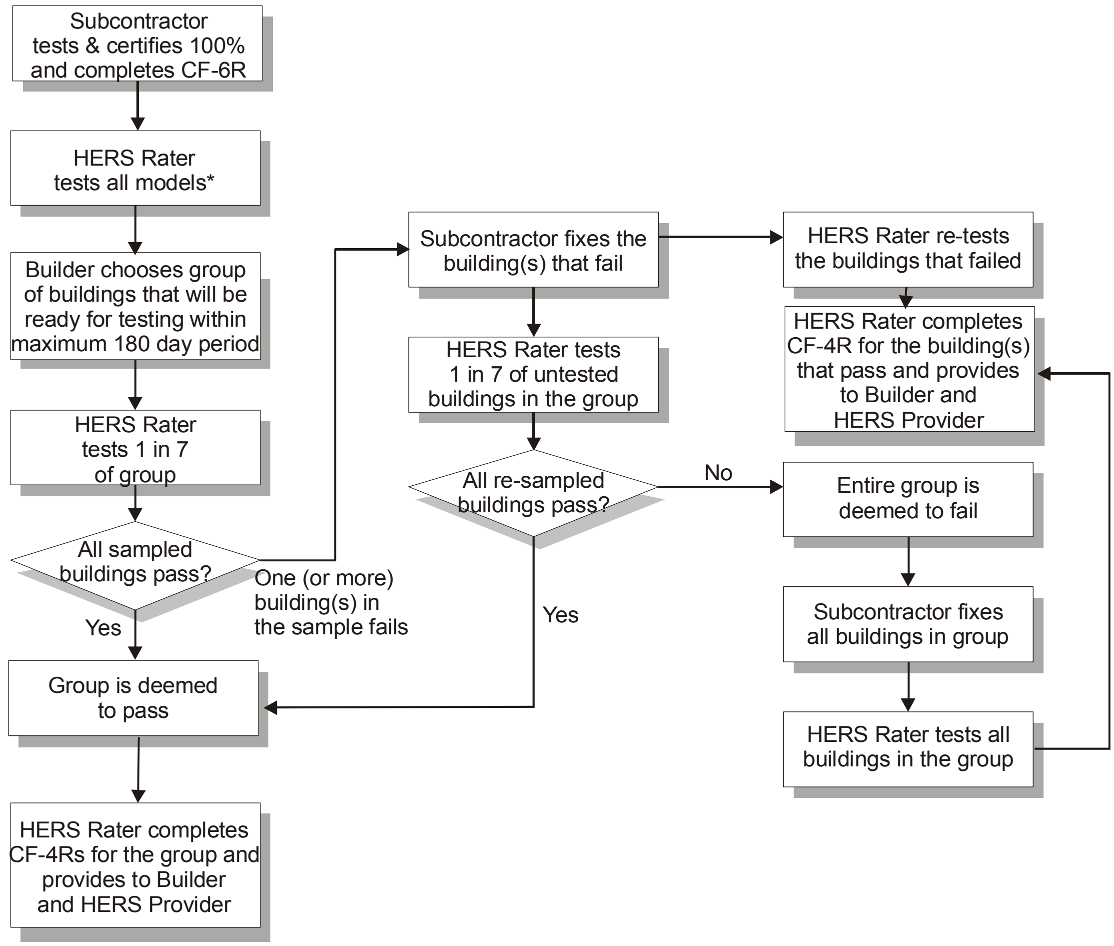
4.4.4 HERS Verification Procedures

At the builder's option HERS field verification and diagnostic testing shall be completed either for each dwelling unit or for a sample of dwelling units. Dwelling units in the sample shall be in the same subdivision or multifamily housing development. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from fan pressurization of ducts in Section 4.3.8.2.1 of Appendix J.

Note that the test (HERS field verification and diagnostic testing for duct sealing compliance credit) must take place with all registers, grilles and supply air diffusers installed.

Figure 4-3 – Simplified Flowchart of the Sampling Process for Diagnostic Testing by a HERS Rater

See Section 4.4.4 for procedural details and Section 4.4.5 for responsibilities and documentation requirements



* Builder may choose to have HERS Rater test 100% of buildings, in which case sampling does not apply.

Field verification and diagnostic testing for compliance credit for refrigerant charge and airflow measurement shall use the standard charge and airflow measurement procedure specified in Appendix L. Field verification and diagnostic testing shall not use the alternate charge and airflow measurement procedure. Field verification and diagnostic testing for refrigerant charge and airflow measurement shall be scheduled and completed when the outside temperature is above 55°F.

The builder shall provide the HERS provider a copy of the CF-6R containing the installation certifications required in Section 4.4.3. Prior to completing field verification and diagnostic testing, the HERS rater shall first verify that the installation certifications have been completed.

If the builder chooses the sampling option, the procedures described in this section shall be followed. For multifamily buildings, also see Section 8.1. Figure 4-3 is a simplified flowchart of the sampling process. The reader is cautioned not to rely solely on Figure 4-3, and to be aware of the procedures described in Section 4.4.4 and the Responsibilities and Documentation requirements in Section 4.4.5.

Initial Field Verification and Testing

The HERS rater shall diagnostically test and field verify the first dwelling unit of each model. To be considered the same model, dwelling units shall be in the same subdivision or multifamily housing development and have the same energy designs and features, including the same floor area and volume, for each dwelling unit, as shown on the CF-1R. This initial testing allows the builder to identify and correct any potential construction flaws or practices in the build out of each model. If field verification and diagnostic testing determine that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* (CF-4R) to the builder and the HERS provider

Sample Field Verification and Testing

After the initial testing is completed, the builder shall identify a group of dwelling units from which a sample will be selected for testing, and notify the HERS provider. For multifamily buildings, see Section 8.1. The group shall include only dwelling units expected to be ready for diagnostic testing within a maximum 180-day period.

The builder shall identify the group of dwelling units by location of County, City and either the street address or the subdivision and lot number, or the multifamily housing project name and shall identify the names and license numbers of subcontractors responsible for the duct installation, duct sealing, thermostatic expansion valve installation, refrigerant charge and airflow measurement or envelope sealing that requires diagnostic testing or field verification. The builder may add additional dwelling units to the group by notifying the HERS provider as long as they are completed within the maximum 180-day period.

The HERS rater shall select a minimum of one out of every seven sequentially completed dwelling units from the group, rounded up to the next whole number, for diagnostic testing and field verification. When several dwelling units are ready for testing at the same time, the HERS rater shall randomly select the dwelling units to be tested. The HERS rater shall diagnostically test and field verify the dwelling units selected by the HERS rater.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider. The *Certificate of Field Verification and Diagnostic Testing* shall report the successful diagnostic testing results and conclusions regarding compliance for the tested dwelling unit.

The HERS rater shall also provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider for up to six additional dwelling units from the group. The *Certificate* shall not be provided for dwelling units in which the feature requiring field verification and diagnostic testing has not been installed, sealed or completed.

The maximum 180-day period shall begin on the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group and shall end either with the date of the last verified test from the group or 180 days, whichever is less. Once all homes in the group have been certified, the 180-day clock is reset. Dwelling units within the group for which a *Certificate of Field Verification and Diagnostic Testing* has not been completed within 180 days from the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group, as determined by the HERS provider, shall either be individually tested or be included in a group of dwelling units in a subsequent sample period.

Whenever the builder changes subcontractors who are responsible for the feature that is being diagnostically field verified and tested, the builder shall notify the HERS rater of any subcontractors who have changed, and terminate sampling for the identified group. All dwelling units using *HERS Required Verification* features for compliance that were installed by previous subcontractors or were subject to verification and testing under the supervision of a previous HERS provider, for which the builder does not have a completed *Certificate of Field Verification and Diagnostic Testing*, shall either be individually tested or included in a separate group for sampling. Dwelling units with installations completed by new subcontractors shall either be individually tested or shall be included in a new sampling group following a new *Initial Field Verification and Testing*.

The HERS rater shall not notify the builder when sample testing will occur prior to the completion of the work that is to be tested. After the HERS rater notifies the builder when testing will occur, the builder shall not do additional work on the features being tested.

Re-sampling, Full Testing and Corrective Action,

When a failure is encountered during sample testing, the HERS rater shall conduct re-sampling to assess whether that failure is unique or the rest of the dwelling units are likely to have similar failings. The HERS provider shall select for re-sampling one out of every seven of all of the untested dwelling units in the group, rounded up to the next whole number.

If testing in all dwelling units in the re-sample confirms that the requirements for compliance credit are met, then the dwelling unit with the failure shall not be considered an indication of failure in the other dwelling units in the group. The builder shall take corrective action for the dwelling unit with the failure, and then the HERS rater shall retest to verify compliance and issue a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder. Sampling shall then resume for the remainder of the group.

If field verification and testing in any of the dwelling units in the re-sample results in a second failure, the builder shall take corrective action in all unoccupied dwelling units in the group that have not been tested but for which a *Certificate of Field Verification and Diagnostic Testing* has been completed. The HERS rater shall conduct field verification and diagnostic testing in each of these dwelling units to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

Builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification and testing and corrective action if necessary. Building owners may decline this offer. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. The HERS provider shall verify that the builder has made this offer. If a building owner in an occupied dwelling unit declines this offer, field verification, testing and corrective action will not be required for that dwelling unit and the dwelling unit will no longer be considered a part of the group. If a building owner accepts this offer, the builder shall take corrective action. The HERS rater shall then conduct field verification and diagnostic testing to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective action, offers to building owners for testing and corrective action and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder. If corrective action requires work not specifically exempted by Section 112 of the CMC or Section 106 of the UBC, the builder shall obtain a permit from the building department prior to commencement of any of the work.

Until corrections, field verification and testing of all dwelling units in the group have been completed or building owners in occupied dwelling units have declined corrective action, sampling of additional dwelling units in the group shall cease. If additional dwelling units in the group are completed during the time required to correct, field verify and test the previously completed dwelling units in the group, the rater shall individually field verify and diagnostically test those additional dwelling units to confirm that the requirements for compliance credit are met. Once corrections, field verification and testing is completed for all dwelling units that have a *Certificate of Field Verification and Diagnostic Testing*, excepting those where building owners have declined corrective action, the builder shall either resume sampling for the remainder of the dwelling units in the group or terminate the group.

Corrections shall not be made to a sampled dwelling unit to avoid a failure. If corrections are made to a sampled dwelling unit, corrections, field verification and testing shall be performed on 100% of the dwelling units in the group.

4.4.5 Responsibilities and Documentation

Builder Responsibilities

Builder employees or subcontractors responsible for completing either diagnostic testing, visual inspection or verification as specified in Section 4.4.3 shall certify the diagnostic testing results and that the work meets the requirements for compliance credit on the CF-6R.

The builder shall provide the HERS provider with the identifying location of the group of dwelling units to be included in the sample for field verification and diagnostic testing and the expected date that sampling may begin. The builder shall provide the HERS provider a copy of the CF-6R signed by the builder employees or sub-contractors certifying that diagnostic testing and installation meet the requirements for compliance credit.

The builder shall provide a *Certificate of Field Verification and Diagnostic Testing* signed and dated by the HERS rater to the building official in conjunction with requests for final inspection for each dwelling unit.

When resampling reveals a failure, builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification, testing and corrective action if necessary. Building owners may decline to have field verification and testing and corrective action completed. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. Builders shall take corrective action as required in all unoccupied dwelling units in the group and in occupied dwelling units in the group where building owners have accepted field verification, testing and corrective action.

HERS Provider and Rater

The HERS provider shall maintain a list of the dwelling units in the group from which sampling is drawn, the dwelling units selected for sampling, the dwelling units sampled and the results of the sampling, the dwelling units selected for re-sampling, the dwelling units that have been tested and verified as a result of re-sampling, the corrective action taken, and copies of all *Certificates of Field Verification and Diagnostic Testing* for a period of five years.

The HERS rater providing the diagnostic testing and verification shall sign and date a *Certificate of Field Verification and Diagnostic Testing* certifying that he/she has verified that the requirements for compliance credit have been met. *Certificates of Field Verification and Diagnostic Testing* shall be provided for the tested dwelling unit and each of up to six other dwelling units from the group for which compliance is verified based on the results of the sample. The HERS rater shall provide this certificate to the builder and the HERS provider.

The HERS rater shall provide a separate *Certificate of Field Verification and Diagnostic Testing* for each dwelling unit the rater determines has met the diagnostic requirements for compliance. The HERS rater shall identify on the *Certificate of Field Verification and Diagnostic Testing* if the dwelling unit has been tested or if it was an untested dwelling unit approved as part of sample testing. The HERS rater shall not sign a *Certificate of Field Verification and Diagnostic Testing* for a dwelling unit that does not have a CF-6R signed by the installer as required in Sections 4.4.3.

If field verification and testing on a sampled dwelling unit identifies a failure to meet the requirements for compliance credit, the HERS rater shall report to the HERS provider and the builder that re-sampling will be required.

If re-sampling identifies another failure, the HERS rater shall report to the HERS provider and the builder that corrective action and diagnostic testing and field verification will be required for all the untested dwelling units in the group. This report shall specify the identifying location of all dwelling units that must be corrected and fully tested.

The HERS provider shall also report to the builder once diagnostic testing and field verification has shown that the failures have been corrected in all of the dwelling units except those for which the building owner has declined field verification, testing and corrective action.

When individual dwelling unit testing and verification confirms that the requirements for compliance have been met, the HERS rater shall provide a *Certificate of Field Verification and Diagnostic Testing* for each previously untested/unverified dwelling unit in the group and for each additional dwelling unit of the same model completed during the time required to correct, verify and test the previously untested/unverified dwelling units in the group.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective actions, offers to building owners for testing and corrective action, and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder.

Building Department

The building department at its discretion may require independent testing and field verification in conjunction with the building department's required inspections, and/or observe the diagnostic testing and field verification performed by builder employees or subcontractors and the certified HERS rater in conjunction with the building department's required inspections to corroborate the results documented in installer certifications, and in the *Certificate of Field Verification and Diagnostic Testing*.

For dwelling units that have used a compliance alternative that requires field verification and diagnostic testing, the building department shall not approve a dwelling unit for occupancy until the building department has received from the builder a *Certificate of Field Verification and Diagnostic Testing* that has been signed and dated by the HERS rater.

If necessary to avoid delay of approval of dwelling units completed when outside temperatures are below 55°F, building departments may approve compliance credit for refrigerant charge and airflow measurement when installers have used the alternate charging and airflow measurement procedure described in Appendix L, Section 3. This approval will be on the condition that installers provide a signed agreement (CF-6R) to the builder with a copy to the building department to return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

4.5 Procedures for HVAC System Design and Installation

The *Standards* have prescriptive and mandatory requirements for duct system design, sealing and installation. A truly quality duct system requires attention to all aspects of duct design, sealing and installation, and performance testing to assure that the system actually delivers comfort to all portions of the home in an energy efficient manner. Incremental improvement, for example through duct sealing alone, may not result in a well performing duct system.

The *Procedures For HVAC System Design and Installation* specified in Appendix K are intended to produce duct systems that are well designed, installed and performance tested to verify their effectiveness in delivering comfort and energy efficiency to home occupants. These procedures comprehensively address all aspects of quality installation of HVAC equipment and duct systems. The Commission highly recommends that builders insure that all aspects of the *Procedures For HVAC System Design and Installation* given in Appendix K are followed.

5 Computer Method

This chapter explains the use of approved public domain and *Alternative Calculation Method (ACM)* computer programs to show compliance with the annual energy budget requirement of the *Energy Efficiency Standards* (*Standards*). These *computer methods* provide a more flexible way to meet the *Standards* compared to the prescriptive packages explained in Chapter 3.

Computer method compliance works by calculating the energy use of the proposed design and comparing it to the allowable energy budget for the standard design. If the proposed design uses equal or less energy than the standard design, then the building complies. This method has the most flexibility because the building designer may trade-off the energy performance of different building components and design features to achieve compliance. The computer method is the most popular compliance method under the *Standards*. The introductory section outlines the basis of the computer method approach and the ACM approval process for the use of computer programs with the *Standards*. Following sections summarize the compliance procedure with computer methods.

Section 5.4 of this Chapter describes computer input values and proposed design modeling techniques. Guidelines for special modeling cases such as zonal controls, controlled ventilation crawl spaces and sunspaces are also contained in Section 5.4. Input descriptions relating to water heating calculations are contained in Chapter 6. Section 5.5 outlines standardized computer method compliance reports using printouts from an approved computer program. Section 5.6 describes how the standard design energy budget is determined.

In addition to the information contained in this Chapter, each approved computer program is required to have a compliance supplement that provides important information regarding the use of that program for showing compliance with the *Standards*.

5.1 Introduction

Computer methods are computer programs approved by the California Energy Commission as being capable of calculating space conditioning and water heating energy use in accordance with a detailed set of rules. The methods simulate or model the thermal behavior of buildings by calculating heat flows into and out of the various thermal zones of the building. Because of their relative accuracy in analyzing annual space conditioning and water heating energy use of different building conservation features, levels and techniques, computer methods are the basis of performance standards as established by the Warren-Alquist Act.

A computer method can perform a significant number of calculations to project the interactive thermal effects of many different building components in conjunction with specific outdoor weather conditions. The calculations include:

- Heat gain and heat loss through walls, roof/ceilings, floors, fenestration and doors
- Solar gain through fenestration as affected by orientation and exterior shading devices.

- Natural ventilation by operable windows and infiltration through cracks and porous surfaces in the building envelope
- Heat storage effects of different types of thermal mass in buildings with large amounts of mass (e.g., passive solar buildings)
- Efficiencies of mechanical heating and cooling equipment and duct systems

The prescriptive packages (Chapter 3) were derived by the Commission from the results of building energy analysis studies using the Commission's reference computer method.

Computer methods are generally the most detailed and flexible compliance path. The energy performance of a proposed building design can be calculated according to actual building geometry, site placement and building features like insulation levels, fenestration performance and equipment efficiencies. Credit for certain conservation features, such as ducts located in conditioned space and reduced building envelope leakage, cannot be taken in the prescriptive packages, but can be evaluated with an approved computer method.

Note: Compliance credit for certain features, such reduced building envelope air leakage, that require diagnostic testing and field verification also require special documentation and processing. See Section 4.3 for diagnostic testing and field verification requirements.

For a computer method to be used for compliance with the *Standards*, the method must first be approved by the Commission. Approval involves the demonstration of minimum modeling capabilities and program documentation. The program must be able to:

- Automatically calculate the **energy budget** based upon the **standard design** (see Section 5.2)
- Calculate the energy use of the proposed design in accordance with specific fixed and restricted inputs
- Perform basic water heating calculations (see Chapter 6)
- Print the appropriate standardized compliance reports (Section 5.5)

Modeling capabilities are tested by using the program to calculate the energy use of certain prototype buildings under specific conditions. The results are then compared with the results from the Commission's reference computer method.

The Commission approves the alternative calculation method according to the procedures outlined in Title 24, Part 1, § 10-101 through § 10-113. The procedures are detailed in the Residential Alternative Calculation Methods Approval Manual. Programs meeting this criteria are referred to as "ACMs" elsewhere in this Chapter.

The Commission periodically updates a listing of approved computer programs. This list may be obtained from the Commission's web site at www.energy.ca.gov/title24 , or Publications Office or by calling the Energy Hotline at (800) 772-3300, and is included in this *Manual* as Appendix F.

5.2 Compliance with a Computer Method

5.2.1 Combined Energy Budget

§ 151(b)

Performance Standards. A building complies with the performance standard if its combined calculated depletable energy use for water heating (§ 151(b)1) and space conditioning (§ 151(b)2) is less than or equal to the combined maximum allowable energy use for both water heating and space conditioning, even if the building fails to meet either the water heating or space conditioning budget alone.

1. Water heating budgets. The budgets for water heating systems are those calculated from Equation 6-2.
2. Space conditioning budgets. The space conditioning budgets for each climate zone shall be the calculated consumption of energy from depletable sources required for space conditioning in buildings in which the basic requirements of § 151(a) and the measures in alternative component package D are installed. To determine the space conditioning budget, use an approved calculation method.

5.2.2 Combined Energy Budget: Space Conditioning and Water Heating Energy Use

Each approved computer method automatically generates an energy budget by calculating the annual energy use of the standard design. The standard design is a building with the same size as the proposed design, but incorporating all conservation features of prescriptive Package D. There are two basic components to the energy budget: space conditioning and water heating. Space conditioning is further divided into space heating and space cooling.

A building complies with the *Standards* if the predicted source energy use of the proposed design is the same or less than the combined annual energy budget for space conditioning and water heating of the standard design. As explained in Chapter 6, the energy budget for water heating energy use varies for each dwelling unit depending on the total conditioned floor area. The budget for space heating and cooling varies according to specific characteristics of the proposed building design.

Since standard design is derived by assuming equal distribution of fenestration area on all four cardinal orientations, the energy budget remains the same regardless of how the actual building is oriented. Variables that affect the energy budget are:

- Conditioned floor area
- Conditioned volume
- Number of stories
- Number of dwelling units
- Gross roof/ceiling area
- Gross wall area
- Slab edge length
- Conditioned Slab-on-grade area
- Raised floor area over crawl space

- Raised floor area over open space
- Heating system type
- Cooling system type
- Space conditioning distribution system type and location
- Climate zone

All other building-related inputs such as area and type of fenestration products, ventilation, HVAC efficiencies and duct efficiencies are automatically fixed in the standard design building according to the Package D requirements and are not accessible for modification by program users.

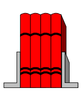
Figure 5-1 – Example Energy Use Summary on C-2R (Page 1)

Energy Summary (kBtu/ft^2-yr)		
	Standard Design Energy Budget	Proposed Design Energy Use
Space Heating	12.34	12.63
Space Cooling	8.97	7.12
Water Heating	11.76	11.76
Total	33.07	31.51

The energy budget and energy use for a building is summarized in an Energy Summary on the Computer Method Summary (C-2R) form illustrated in Section 5.5 and Figure 5-1. The Standard Design Energy Budget is calculated according to the rules and assumptions explained in Section 5.6, and represents the total allowable energy budget for the building.

The Proposed Design Energy Use must be equal to or less than that of the Standard Design Energy Budget for the building to comply.

5.2.3 Compliance Demonstration



§151(c)

Compliance Demonstration Requirements for Performance Standards. The application for a building permit shall include documentation that demonstrates, using an approved calculation method, that the new building has been designed so that its energy use from depletable energy sources does not exceed the combined water heating and space conditioning energy budgets for the appropriate climate zone.

Although any one or two components of the energy use may be higher than the same component in the energy budget (e.g., 12.63 kBtu/ft^2-yr versus 12.34 kBtu/ft^2-yr space heating), the combined energy use of the Proposed Design must be less than or equal to the combined energy budget of the Standard Design (e.g., 31.51 versus 33.07 kBtu/ft^2-yr). In this way, trade-offs can be made among water heating, space heating and space cooling energy use (see §151(b) of the *Standards*).

5.2.4 Additions

An approved computer method may be used to show compliance of an addition alone, or to show compliance of an addition accounting for the energy performance of the existing building. These approaches are explained in Sections 7.3 and 0.

5.3 General Compliance Procedure

Any approved computer method may be used to comply with the *Standards*. The following steps are a general outline of the typical computer method procedure:

1. Collect all necessary data—areas of fenestration products, walls, doors, roofs, ceilings and floors, construction assemblies, solar heat gain coefficients, equipment efficiencies, water heating information—from drawings and specifications. Although most computer methods require the same basic data, some information and the manner in which it is organized may vary according to the particular program used. Refer to the compliance supplement for the program being used for additional details.
2. If appropriate default U-factors for wall, roof/ceiling and floor are used (see Section 5.4, item B4), no Form 3Rs are submitted. If default values are not used, prepare the appropriate Forms 3R for the various proposed construction assemblies either through the use of the program or by hand calculation (see R-Value in the Glossary).
3. Prepare an input file describing the other thermal aspects of the proposed design according to the rules described in Section 5.4 and in the program's compliance supplement. Input values and assumptions must correctly correspond to the proposed design and conform to the required mandatory measures described in Chapter 2.
4. Generate a computer run to automatically calculate the Standard Design Energy Budget and the Proposed Design Energy Use.
   a. If the water heating system is a "standard system" as explained in Chapter 6, the water heating energy use is assumed to be the same for both the standard and proposed designs.
   b. If any other water heating system is to be used or if credit is being taken for a more conserving aspect of the water heating system, water heating energy use is calculated by the approved program as explained in Chapter 6. The computer printout must show the details of the water heating system that was modeled.

The building complies if the total energy use of the proposed design is the same or less than the standard design energy budget.

Professional Judgment. As explained in the next section, some modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. There is little or no freedom to choose input values for compliance modeling purposes. However, other aspects of computer modeling remain for which some professional judgment is necessary. In those instances, exercise proper judgment in evaluating whether a given assumption is appropriate.

Building departments have full discretion to reject a particular input, especially if the user has not substantiated the value with supporting documentation.

Two questions may be asked in order to resolve whether professional judgment has been applied correctly in any particular case:

- Is a simplifying assumption appropriate for a specific case? If simplification reduces the predicted energy use of the proposed building when compared to a more explicit and detailed modeling assumption, the simplification is not acceptable (i.e., the simplification must reflect higher energy use than a more detailed modeling assumption).

- Is the approach or assumption used in modeling the proposed design consistent with the approach or assumption used in generating the energy budget?

One must always model the proposed design using the same assumption and/or technique used by the program in calculating the energy budget unless drawings and specifications indicate specific differences that warrant conservation credits or penalties.

Any unusual modeling approach, assumption or input value should be documented with published data and should conform to standard engineering practice.

For assistance in evaluating the appropriateness of particular input assumptions, call the Energy Hotline (see Section 1.6) or call the vendor of the computer program (see Appendix F).

Note: When creating a computer input file, use the space provided for the project title information to concisely and uniquely describe the building being modeled. User-designated names should be clear and internally consistent with other orientations and/or buildings being analyzed. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement process.

5.4 Proposed Design Modeling Procedure

This section summarizes the modeling and output information used in demonstrating compliance with approved computer methods. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program.

Input data entered into each approved computer method may be organized differently from one to the next. As a result, it is not possible in this summary to present all variables in their correct order or hierarchy for any one program. The aim is to identify a generic type of input variable and explain how it should be treated in the context of properly modeling the proposed building design for compliance. Descriptions of particular values are cross-referenced to key outputs shown on the sample Computer Method Summary (C-2R) forms in Section 5.5. Modeling assumptions used by the computer methods to calculate the standard energy budget are outlined in Section 5.6.

The following general reference categories may be used to find specific input/output descriptions that are grouped accordingly:

Table 5-1 – General Reference Categories for Input/Output Descriptions

MINIMUM CAPABILITIES	OPTIONAL CAPABILITIES
A. Building Information	N. Controlled Ventilation Crawl Space (CVC)
B. Walls, Doors, Roofs/Ceilings and Floors	O. Zonal Control
C. Fenestration	P. Attached Sunspaces
D. Shading Devices and Overhangs	Q. Combined Hydronic Space/Water Heating
E. Thermal Mass	R. Exterior Mass Walls
F. Natural Ventilation	S. Solar Water Heating
G. Mechanical Ventilation	T. Side Fin Shading
H. Infiltration Gains and Losses and Reduced Building Envelope Air Leakage	U. Gas-Fired Heat Pumps
I. Internal Gain & Thermostat Setpoints	V. Form 3 Report Generator
J. Space Conditioning System Efficiency and Distribution (Duct) System Efficiency	
K. Water Heating Efficiency and Distribution System	
L. Radiant Barrier and Cool Roofs	
M. Building Additions Modeled with or without Existing Buildings	

5.4.1 Building Information

Project Title Information A1

The project title should be used to clearly identify and distinguish one project, building, unit plan and/or orientation from another. Include as much title description as is useful.

Number of Dwelling Units A2

The number of dwelling units determines the value used for internal heat gain and the water heating energy budget in multi-family buildings.

When modeling an addition alone, the dwelling unit number is the fraction obtained by dividing the square foot area of the addition by the square foot area of the existing building plus addition.

Number of Stories A3

The number of habitable stories in the proposed design. A habitable story is defined as a story that contains space in which humans may work or live in reasonable comfort, and that has at least 50% of its volume above grade.

In the case of a second story addition modeled alone, the number of habitable stories in the proposed design should be input as "2". Single-family dwelling units with more than 3 stories may use an input of 3 stories.

Building Type A4

Building types are: Single Family (includes duplexes and halfplexes), Multi-Family (includes all other attached dwellings including condominiums), Addition, Existing-Plus-Addition or Alteration. The building type identifies for the computer programs which of the different modeling algorithms for internal heat gain and infiltration are used for the calculation of a particular energy budget.

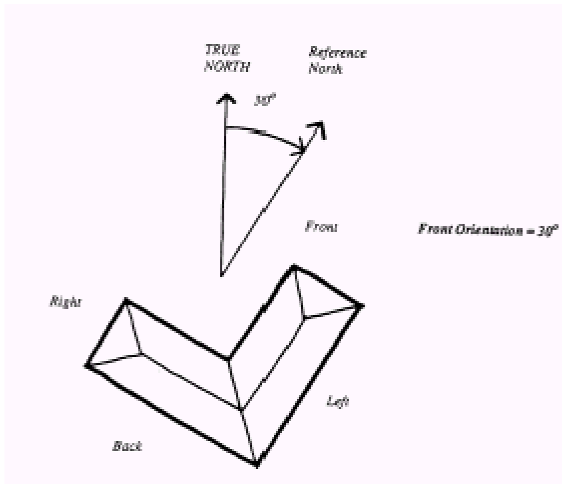
Front Orientation A5

This is a value that represents the rotation of the reference "Front" side or reference "Front" elevation of the building with respect to true north, expressed in degrees (see Figure 5-2). When compliance is demonstrated for all orientations, the reference orientation can be reported as North.

TRUE NORTH =	0	= True North
	90	= True East
	180	= True South
	270	= True West

Note: The "front" or "entry" door of the building may not necessarily be located in the wall designated in the drawings as the "Front" elevation. Any side of the building may be identified as the front as long as the output accurately reflects the orientation of opaque and fenestration surfaces.

Figure 5-2 – Determining Front Orientation



Total Conditioned Floor Area A6

Total conditioned floor area of the building, in square feet. See the Glossary for a full definition.

Conditioned Slab Floor Area

The conditioned slab area is the area of slab floor with conditioned space above and the ground (slab-on-grade) or unconditioned space below (raised slab). This input and the Total Conditioned Floor Area are used to determine the thermal mass modeled in the Proposed Design and the Standard Design.

Volume A7

Volume of all conditioned space, in cubic feet. This value is the product of total conditioned floor area and area-weighted average ceiling height.

Climate Zone A8

The specified climate zone allows the program to use the fixed weather data established by the Commission. Depending on the program, the city specified may automatically call the correct climate zone. Consult Appendix D or the program compliance supplement.

5.4.2 Walls, Doors, Roofs/Ceilings & Floors

Exterior Walls, Doors, Roofs/Ceilings and Raised Floors B1

Exterior surfaces are defined as surfaces that separate conditioned space from outdoor conditions or unconditioned spaces. See Unconditioned Space, Controlled Ventilation Crawl Space and the program compliance supplement for further information.

Each exterior surface has associated with it a user-defined name (which may not appear on compliance output), area, U-factor, orientation, tilt and absorptivity as described below.

The mass effect of exterior masonry walls may be modeled by computer methods with that optional capability. In those cases, exterior wall inputs include thermal mass attributes described in Subpart 5.4.5 and in the program compliance supplement.

Straw bales that are 23 inches by 16 inches are assumed to have a thermal resistance of R-30. (Performance data on other sizes of bales was not available at the time of publication of this *Manual*.) The minimum density of load bearing walls is 7.0 pounds per cubic foot, or the actual density. Specific heat is set to 0.32 Btu/lb/°F. Volumetric heat capacity is calculated as density times specific heat (at 7 lb/ft^3 the volumetric heat capacity is 2.24 Btu/ft^3/°F).

Name B2

A user-defined name should be used to clearly distinguish one wall or ceiling from another. When a building is to be run for compliance in all four orientations, "front" and "rear" designations are recommended instead of "north" and "south" (see Front and Back in the Glossary).

Note: user-defined names may be used and appear on input screens but the ACM must generate names such as WALL01 for compliance output.

Area B3

Net area of the exterior wall, basement wall/floor, roof/ceiling or raised floor, in square feet. The net area does not include the area of fenestration products and doors which are treated separately.

Some programs may allow the user to enter gross exterior wall area and automatically subtract the area of fenestration and doors. Consult the program compliance supplement.

Exterior wall area is measured from the lowest finished habitable floor to the ceiling of the uppermost floor.

Basement walls include below grade walls at depths of 2 feet, 2 to 6 feet, and greater than 6 feet. Above grade walls are modeled as conventional walls.

Floor and ceiling areas include the thickness of exterior walls. Vaulted roof/ceiling areas must be calculated for the surfaces through which heat loss occurs (e.g., insulation in a flat ceiling area or in a sloped roof area). Unless gross areas are used, skylight area is subtracted when computing net roof/ceiling areas.

U-factor B4

The U-factor of the construction assembly, in Btu/(ft^2-hr-°F) (see the Glossary). Standard U-factors shown in Table 5-2 may be used instead of completing and submitting a Form 3R. If a Form 3R is calculated (see R-Value in the Glossary), the "Total U-factor" from the bottom of the form is used in the calculations.

Ceiling U-factors are reduced by the ACM if an approved radiant barrier is installed.. See Subpart 5.4.14 for details.

Note: In the case where metal framing is used the overall U- factor of the assembly cannot be determined by using the Form 3R. To properly account for the high thermal conductivity of metal, the tables and methodology included in the Appendices for metal framing must be used to calculate a correct value.

Orientation B5

This is an input value representing the orientation of the exterior surface with respect to the reference "front" elevation, or relative to the front.

The "left" elevation is 90°, the "rear" elevation is 180°, the "right" elevation is 270°, and the "front" elevation is 0°. Surfaces at angles are calculated relative to the front elevation (0°).

Note: The C-2R printout shows actual orientation of each opaque and fenestration surface based on the rotation specified building front orientation

Tilt B6

The tilt of the exterior surface is defined to be 0° for a horizontal (face up) roof/ceiling, 90° for a vertical wall and 180° for a floor (face down).

Solar Gains B7

Solar gains is either "Yes" for all exterior surfaces exposed to any direct sunlight or "No" for surfaces that do not receive direct solar gain (e.g., a wall separating conditioned space and a garage).

Table 5-2A – Standard U-factors of Wood Frame Roofs/Ceilings and Walls[1]

Roof/Ceiling Insulation	*Framing Spacing*	*Reference[2] Name*	*U-factor*
R-0[3]	16" o.c.	R.0.2X6.16	0.297
R-0[3]	24" o.c.	R.0.2X4.24	0.305
R-11[3]	16" o.c.	R.11.2X6.16	0.076
R-11[3]	24" o.c.	R.11.2X4.24	0.076
R-13[3]	16" o.c.	R.13.2X6.16	0.069
R-13[3]	24" o.c.	R.13.2X4.24	0.068
R-19	16" o.c.	R.19.2X8.16	0.051
R-19	24" o.c.	R.19.2X4.24	0.047
R-22	16" o.c.	R.22.2X10.16	0.044
R-22	24" o.c.	R.22.2X4.24	0.041
R-30	16" o.c.	R.30.2X10.16	0.036
R-30	16" o.c.	R.30.2X12.16	0.035
R-30	24" o.c.	R.30.2X4.24	0.031
R-38	16" o.c.	R.38.2X12.16	0.030
R-38	16" o.c.	R.38.2X14.16	0.028
R-38	24" o.c.	R.38.2X4.24	0.025
R-49	16" o.c.	R.49.2X4.16	0.019
R-49	24" o.c.	R.49.2X4.24	0.019
Wall Insulation			
R-0[3]	16" o.c.	W.0.2X4.16	0.385
R-0[3]	24" o.c.	W.0.2X4.24	0.392
R-7[3]	16" o.c.	W.7.2X4.16	0.130
R-7[3]	24" o.c.	W.7.2X4.24	0.127
R-11[3]	16" o.c.	W.11.2X4.16	0.098
R-11[3]	24" o.c.	W.11.2X4.24	0.094
R-13	16" o.c.	W.13.2X4.16	0.088
R-13	24" o.c.	W.13.2X4.24	0.084
R-15	16" o.c.	W.15.2X4.16	0.081
R-15	24" o.c.	W.15.2X4.24	0.077
R-19	16" o.c.	W.19.2X6.16	0.065
R-19	24" o.c.	W.19.2X6.24	0.063
R-21	16" o.c.	W.21.2X6.16	0.059
R-21	24" o.c.	W.21.2X6.24	0.056
R-25	16" o.c.	W.25.2X6.16	0.046
R-29	16" o.c.	W.29.2X4.16	0.035
R-30	No Framing[4]	Straw	0.033
Solid core wood door (no insulation)		D.0.SCW	0.330

1. Based on ASHRAE Parallel Heat Flow Calculation, ASHRAE Handbook of Fundamentals.
2. These Reference Names are taken from Appendix H. Roof/ceiling assemblies listed with 2x4 framing include an attic space.
3. Does not meet the minimum level required as a mandatory measure (see Section 2.2).
4. Framing that penetrates no more than 25% of the way through the strawbale.

Table 5-2B – Standard U-factors of Wood Frame Raised Floors[1]

Floor Insulation	Condition	Reference[2] Name	U-factor
R-0[3]	No crawl space	FX.0.2X6.16	0.238
R-0[3]	Crawl space	FC.0.2X6.16	0.097
R-11[3]	No crawl space	FX.11.2X6.16	0.071
R-11[3]	Crawl space	FC.11.2X6.16	0.049
R-13	No crawl space	FX.13.2X6.16	0.064
R-13	Crawl space	FC.13.2X6.16	0.046
R-19	No crawl space	FX.19.2X8.16	0.048
R-19	Crawl space	FC.19.2X8.16	0.037
R-21	No crawl space	FX.21.2X8.16	0.045
R-21	Crawl space	FC.21.2X8.16	0.035
R-30	No crawl space	FX.30.2X10.16	0.034
R-30	Crawl space	FC.30.2X10.16	0.028

1. Based on ASHRAE Parallel Heat Flow Calculation, ASHRAE Handbook of Fundamentals.
2. The Names given to the standard assemblies used to calculate these U-factors in Appendix H.
3. Does not meet the minimum level required as a mandatory measure (see Section 2.2).

Table 5-2C – Standard U-factors of Wood Foam Panel Roofs/Ceilings and Walls[1]

Roof/Ceiling	Framing	Reference[2]	
Insulation	Spacing	Name	U
Value			
R-14[3]	48" o.c.	RP.14.2X4.48	0.064
R-22	48" o.c.	RP.22.2X6.48	0.044
R-28	48" o.c.	RP.28.2X8.48	0.035
R-36	48" o.c.	RP.35.2X10.48	0.029
Wall Insulation			
R-14	48" o.c.	WP.14.2X4.48	0.071
R-22	48" o.c.	WP.22.2X6.48	0.049

1. Based on ASHRAE Parallel Heat Flow Calculation, ASHRAE Handbook of Fundamentals.
2. The names given to the standard assemblies used to calculate these U-factors in Appendix H.
3. Does not meet the minimum level required as a mandatory measure (see Section 2.2).

Slab-On-Grade B8

Slab floors coupled directly to the ground (i.e., poured directly on grade) fall into this category. Post-tensioned slabs suspended over a garage, for example, are treated as exterior (raised) floors but are included as part of the Conditioned Slab Floor Area.

Thermal mass characteristics of slab floors are explained in Section 5.4.5.

Slab Area B9

The gross area of slab-on-grade, in square feet. This value is needed for the program to calculate the net area of covered slab and the conditioned footprint area of the building.

Slab Edge Length B10

The length of slab edge through which there is heat loss, in feet. The slab edge length is fixed to assume 80% is carpeted or covered and 20% is exposed to conditioned air in ACM calculations.

Slab heat transfer is modeled through the slab edge. The heat flow is a function of the surface treatment of the slab, and the R-value and depth of any edge insulation (B11).

Slab Edge F2 Factor B11

Slab Edge Insulation Depth and R-Value or F2 Factor. The F2 factor defines the slab loss per linear foot of slab edge. Depending on the program, the user specifies the F2 factor directly or may specify the insulation depth and R-value and allow the program to calculate the F2 factor.

Any portion of a slab edge located between conditioned space and an attached and enclosed conditioned space (e.g., a garage or crawl space) may be modeled as if R-7 insulation is installed to a depth of 16". In climate zones 1 and 16 only, slab edges adjacent to an entry slab may also be calculated as if R-7 insulation is installed to a depth of 16". The perimeter length of bermed (under ground) walls is modeled as slab edge.

Note: In a building with a hydronic radiant slab floor heating system (see Section 8.8), the required slab edge insulation depends on climate and the location of the insulation. However, the slab must be modeled without credit for slab edge insulation.

Table 5-2D – Standard U-factors of Steel Frame Walls[1]

Wall Insulation	Insulation Sheathing R-Value	Framing Type	Framing Spacing	U-factor[2,3]
R-11[3]	0	2x4	16" o.c.	0.202
R-11	7	2x4	16" o.c.	0.084
R-11[3]	0	2x4	24" o.c.	0.173
R-11	7	2x4	24" o.c.	0.078
R-13[3]	0	2x4	16" o.c.	0.195
R-13	7	2x4	16" o.c.	0.082
R-13[3]	0	2x4	24" o.c.	0.165
R-13	7	2x4	24" o.c.	0.077
R-15[3]	0	2x4	16" o.c.	0.189
R-15	7	2x4	16" o.c.	0.077
R-15[3]	0	2x4	24" o.c.	0.158
R-15	5	2x4	24" o.c.	0.088
R-19[3]	0	2x6	16" o.c.	0.162
R-19	7	2x6	16" o.c.	0.075
R-19[3]	0	2x6	24" o.c.	0.135
R-19	4	2x6	24" o.c.	0.088
R-21[3]	0	2x6	16" o.c.	0.157
R-21	5	2x6	16" o.c.	0.088
R-21[3]	0	2x6	24" o.c.	0.130
R-21	4	2x6	24" o.c.	0.086
R-22[3]	0	2x6	16" o.c.	0.158
R-22	5	2x6	16" o.c.	0.088
R-22[3]	0	2x6	24" o.c.	0.132
R-22	4	2x6	24" o.c.	0.086

1. Based on ASHRAE Heat Flow Calculation, ASHRAE Handbook of Fundamentals.
2. The U-factor must be no greater than 0.088 to comply. See also Appendix I, Table I-1.
3. Does not meet the minimum level required as a mandatory measure (see Section2.2).

5.4.3 Fenestration

Fenestration C1

Fenestration products include all windows, skylights and exterior doors with glazing (see Section 2.3 and the Glossary.) All fenestration must be modeled if it separates conditioned space from the outside or from unconditioned space. In some special cases, fenestration is not modeled as exterior surface (e.g., in the case of an unheated sunspace) as explained in the program compliance supplement. See Unconditioned Space later in this section and the program compliance supplements.

Fenestration Name C2

The user-defined name should be used to indicate the type of fenestration product and associated shading.

When a building is to be run in all four orientations, "front" and "back" designations should be used instead of "north" and "south" (see Front in the Glossary).

Area C3

The sash or frame opening area of the fenestration product, in square feet (see Glossary). The area calculated from the nominal or rough opening dimensions is generally acceptable. The full area of French doors must be included, as well as the rough opening of greenhouse/garden windows.

A greenhouse/garden window is a window that projects from the building but does not extend to the ground and is not intended for use as a habitable space (e.g., used for shelves).

U-factor C4

The rated U-factor of the fenestration product, in Btu/hr-ft^2-°F. This is the U-factor that the manufacturers display as a label on all windows and skylights. Section 2.3 for a discussion of window, glass door and skylight ratings.

Orientation C6

The orientation of the glazing surface with respect to the "front orientation" (see Figure 5-2).

The "left" elevation is 90°, "back" elevation is 180°, right elevation is 270°, and "front" elevation is 0° for a typical building. See A5, Front Orientation, and B6, Wall Orientation, in this section.

Note: The C-2R printout shows actual orientation of each opaque and glazing surface is based on the specified Front Orientation.

Tilt C7

The tilt of the fenestration is defined to be 0° for a horizontal skylight and 90° for a vertical window or clerestory. The actual tilt of the fenestration should be entered (e.g., 18° for a skylight in a 4:12 roof pitch).

Operable Window Type C8

Acceptable opening types are Slider, Hinged (casement, French door, awning or hopper), or Fixed (picture window). The default for windows is Slider. To determine the standard design, the assumption is that all fenestration openings are operable slider type. Some ACM's do not provide this input and use the default Slider instead. Consult compliance supplement for further information.

The area of operable fenestration is important in the natural ventilation effectiveness calculated by the program.

When credit for hinged operable fenestration is taken, all fixed fenestration areas must also be accounted for as part of the calculation of total vent area:

Equation 5-1

$$Vent_{area} = (Area_{slider} \times 0.1) + (Area_{hinged} \times 0.2) + (Area_{fixed} \times 0.0)$$

When the area of hinged windows are entered, the area of sliders must also be entered and the area of fixed windows must equal the difference between the total fenestration area and the sum of the areas of the sliders and hinged fenestration or a program error will result.

Free vent area is divided up into 50% of the total free vent area as inlet area and 50% of the free vent area as outlet area. Although this calculation is done automatically within the program, the equation is needed to area-weight height differences between inlet and outlet vents as explained in F7.

5.4.4 Shading

Shading Characteristics D1

Shading can be defined as a fixed overhang and/or side fins relating to a particular glass area; as a fixed exterior screen or shade with a specified solar heat gain coefficient; or as a window with shading properties (e.g. low solar gain glass). For a full explanation of Shading, see the Glossary and consult the program compliance supplement.

SHGC Fenestration D2 — The SHGC for the fenestration product, which includes the shading effects of framing and dividers, is obtained from manufacturer's literature, product label, or from Table G-8 (see Solar Heat Gain Coefficient in the Glossary).

Interior Shade D3 — Interior shading is not a compliance variable. Approved ACMs are required to model a standard drape for windows and no drape for skylights. The standard drape is a modeling assumption and is not required to be installed or present at final inspection

Exterior Shade D4 — Credit for exterior devices is determined from the description of the exterior shading device:

Table 5-3 – Descriptors for Exterior Shading Devices

Descriptor	Exterior Shading Device
Standard	Bug Screen
WvnScrn	Woven SunScreen
LvrScrn	Louvered SunScreen
LSASnScrn	Low Sun Angle (LSA) Sunscreen
RlDwnAwng	Roll-down Awning
RlDwnBlnds	Roll -down Blinds or Slats
None	None (Skylights Only)

Note that "None" is only allowed for skylights and is the default exterior shade for skylights.

Height of Shaded Fenestration D5 — Height of fenestration to be shaded, in feet.

In most programs, fenestration height is used only to establish the geometry of the shading condition for overhangs and fins, not to compute fenestration area (which is entered elsewhere.)

For a particular overhang, the area-weighted average height may be used if combining different windows is judged appropriate according to Section 5.2 of this chapter.

Width of Shaded Fenestration D6 — Width of fenestration to be shaded, in feet.

Fenestration width is used generally to establish the geometry of the shading condition for overhangs and fins, not to compute fenestration area (which is input elsewhere).

An average fenestration width may be used if combining different windows is judged appropriate according to Section 5.2 of this chapter.

Overhangs D7 — Dimensions which describe an overhang above the fenestration, in feet: Depth of the overhang, vertical distance from the top of the fenestration to the overhang, extension of the overhang at the sides, height of the overhang flap (depending on the program). Consult the program compliance supplement for further information.

Fins D8 — Dimensions which describe side fins to the left and/or right of the fenestration, in feet: Depth of fins, extension of fins above the fenestration, distance from the fins to the fenestration and the extension of fenestration below the fins (depending upon the program). Consult the program compliance supplement for further information.

Substantially Shaded Fenestration D9 — Substantially shaded fenestration may be modeled with an exterior solar heat gain coefficient of 0.20. For more details on the requirements that must be met, refer to Solar Heat Gain Coefficient in the Glossary.

5.4.5 Thermal Mass

Thermal mass credit is restricted to buildings designed to take advantage of thermal mass such as passive solar designs. For typical buildings there is no credit because thermal mass is modeled the same for both the Proposed Design and the Standard Design. Thermal mass receives credit only when the amount of mass in the Proposed Design exceeds a high mass threshold equivalent to 30% exposed slab-on-grade. Refer to the program compliance supplement to learn more about specific thermal mass modeling techniques and optional capabilities.

Mass Material Name E1 A user-defined name for a thermal mass material not already included as part of the program's materials library.

Surface Area E2 Surface area of the thermal mass, in square feet. If both surfaces of an interior mass wall are exposed to conditioned space, use half the thickness of the wall and the total area of both wall surfaces. Both surfaces are coupled to zones called "House" (see E7).

The surface area of covered slab-on-grade is the calculated exposed slab area subtracted from the total gross slab area. Unless the amount of exposed slab-on-grade area exceeds the mass threshold, there will be no difference in the compliance results when the entire slab area is modeled as a covered slab.

Thickness E3 Thickness of the thermal mass, in inches. If both surfaces of a solid interior mass wall such as grouted concrete block are directly exposed to conditioned air, the full thickness of the wall should be assigned to the mass element which is then coupled to two "House" zones as explained in E2 and E7.

Volumetric Heat Capacity E4 Heat capacity of one cubic foot of the material, in Btu/ft^{3}°F. Consult the compliance supplement for the specific program being used to select the appropriate value for a generic mass material listed in Table G-12.

Conductivity E5 Thermal conductivity of the mass material, in Btu/hr-ft^{2}-°F. Consult the compliance supplement for the specific program being used to select the appropriate value for a generic mass material.

Surface Resistance E6 Heat transfer at the surface of the mass is expressed as thermal resistance, in (hr-ft^{2}-°F)/Btu.

This value is used to account for a treatment such as carpet which, like any "covered" surface, is assumed to have a surface resistance of R-2.0. In modeling a slab-on-grade building, all mass area that is not exposed is assumed to be covered.

Mass Coupling E7 The coupling of the thermal mass defines the building zone (e.g., "house") or temperature condition to which the mass surface is connected. Each side of the mass is coupled either to a conditioned space, an unconditioned space or the ambient (outdoor) conditions.

Thermal mass is considered "interior" if all of its surface area, such as both sides of a masonry partition are exposed to the conditioned space. Thermal mass coupled to conditioned space on one side and exposed to outdoor conditions on the other side is "exterior" mass. The CF-1R and C-2R forms (see Section 5.5 and Appendix A) make clear which type of mass is included in the proposed design.

5.4.6 Infiltration/Ventilation and Reduced Building Envelope Air Leakage

Approved computer programs use a default building envelope air leakage (expressed in terms of Specific Leakage Area, SLA) for proposed designs when the user does not intend to take compliance credit for building envelope sealing. The default is set at 4.9 SLA except for dwellings using non-ducted HVAC systems where the default SLA is 3.8 for both the Proposed and Standard Designs. Careful attention to building envelope sealing would result in significantly lower SLA levels which may be modeled subject to verification by a HERS rater.

Reduced Building Envelope Air Leakage through Diagnostic Testing F1

Compliance credit can be taken for reduced building envelope leakage verified through diagnostic blowerdoor testing as described in Chapter 4.

There are special mechanical ventilation requirements when the building is designed for low building envelope leakage and mechanical **supply** ventilation requirements when diagnostic testing indicates that the building is “unusually tight.” These are described in Chapter 4.

Mechanical Ventilation Wattage of Ventilation Supply and Exhaust Fans F2

The total power consumption of the continuous supply ventilation fans and continuous exhaust fans are input when compliance credit is taken for reduced building envelope leakage and mechanical ventilation is installed.

Ventilation Supply and Exhaust Fans F3

The volumetric capacity of continuous supply fans and continuous exhaust fans are input when continuous mechanical ventilation is installed.

Reduced Duct Leakage F4

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special “default” compliance credit can be taken for building envelope leakage reduction resulting from reduced duct leakage. To qualify for this credit all requirements of Section 4.1.7 must be met. Compliance credit is provided for a “default” reduction in Specific Leakage Area of 0.50.

Air Retarding Wrap F5

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special “default” compliance credit can be taken for building envelope leakage reduction resulting from installation of an air retarding wrap (i.e., housewrap). There are special qualifications for the use of these wraps to get credit which are described in Chapter 4.

When compliance credit is taken for an air-retarding wrap, the computer program must automatically include the air retarding wrap and the required specifications in the Special Features and Modeling Assumptions section of the CF-1R and C-2R to facilitate inspection by the local enforcement agency. Compliance credit for an air retarding wrap does not require HERS rater verification.

Compliance credit is provided for a “default” reduction in Specific Leakage Area of 0.50.

Natural Ventilation for Cooling F6

Approved compliance programs assume that windows are opened for natural ventilation when outside temperatures are conducive for providing outside cooling. For buildings with typical thermal mass levels, default assumptions for natural ventilation are used. For high mass buildings, compliance credit can be taken for increased free ventilation window area and increased ventilation height.

Ventilation Height Difference F7

A height difference of 2 feet is input for one-story dwelling units (even if the dwelling unit occurs in a two or three-story building). A value of 8 feet is input for two and three-story dwelling units.

A different value for the height difference between horizontal center lines of inlet and outlet openings corresponding to the actual building design is acceptable if properly documented. An area-weighted calculation is required to document credit for any value larger than the standard value.

5.4.7 Internal Gain & Thermostat Setpoints

Internal Heat Gain G1

Total internal heat gain per day from occupants, lights, appliances and other heat-generating equipment is automatically fixed by the program according to the number of dwelling units in the building and the total conditioned floor area. The hourly schedule of internal gain is also fixed.

In modeling additions, the internal heat gain associated with the addition as a separate compliance entity is also calculated by the program on a prorated basis as compared with the existing-plus-addition (see Section 7.3.3).

Internal gain related to modeling a zonally-controlled space is also automatically fixed by the program. The living zone and sleeping zone are assigned various portions of the internal gain according to specific rules (see M1, Zonal Control in this section).

Thermostat Setpoints G2

Thermostat setpoints for heating, cooling and venting are fixed by the program based on setback or no setback. Settings are inaccessible by the program user. Special thermostat settings for the zonal control model are also built in and automatically used when zonal control is specified in computer methods approved with that approach (see M1, Zonal Control in this section).

Certain types of heating and cooling equipment are exempt from the setback thermostat mandatory measure (see Section 2.5.3). When no setback thermostat is installed, the computer method must assume a 66°F night setback heating setpoint.

The program also allows the specification of unconditioned zones with thermostats set to insure that no heating or cooling occurs in those areas (see Section 5.4.11, Unconditioned Space).

5.4.8 Space Conditioning System

Heating System Type H1

Heating system types include gas, heat pump and electric resistance. Gas refers to any non-electric fuel such as natural gas, oil or propane. **Hydronic Space Heating** (see Section 5.4.16) and **Active Solar Space Heating** (see Section 5.4.19) are covered later in this section.

Heating System Efficiency H2

The heating system for the standard design depends on the type of system specified for the proposed design. The difference between the proposed design system and the standard design system is an important factor in compliance. Table 5-4 shows the mapping between the proposed design system and the standard design system. For instance, if the proposed design system is a central gas furnace, then the standard design system is also a central gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 78%, which is equal to the prescriptive requirement. The standard design system also has sealed R-4.2 ducts (6% leakage) located in the attic. An electric resistance baseboard heating system, on the other hand, is compared to a split system heat pump with sealed air distribution ducts located in the attic and insulated with R-4.2 insulation. Non-ducted, non-central gas heaters are compared to non-ducted systems of the same type, but with an AFUE meeting minimum efficiencies. All standard design systems have setback thermostats and no zonal control.

Table 5-4 – Heating System Standard Design Map

Proposed Design System	Standard Design System
Gas or other fossil fuel furnace with air distribution ducts Hydronic systems of any type of distribution, including radiant panels, baseboards or fan coils Wood heating system (Note 1)	Gas furnace 78% AFUE R-4.2 sealed ducts located in attic (Note 2)
Gas wall furnaces, floor furnaces, room heaters Other non-ducted, non-central gas fired heating systems Other gas heating appliances	Gas furnace AFUE depends on unit size and type (See Table G-1) No air distribution ducts
Split system central heat pump with air distribution ducts Split system central heat pump with no air distribution ducts Electric baseboard heating system (Note 3)	Split system heat pump HSPF = 6.8 R-4.2 sealed ducts located in attic (Note 2)
Room electric heat pump	Packaged heat pump HSPF = 6.6 No air distribution ducts
Packaged heat pump with air distribution ducts	Packaged heat pump HSPF = 6.6 R-4.2 sealed ducts located in attic (Note 2)

Notes

1. The proposed design for houses with wood heating systems is modeled the same as the standard design so there is no credit or penalty related to wood heat. If the software does not have a choice for wood heat, then the compliance author must specify a gas furnace with an AFUE of 78% and sealed R-4.2 ducts in the attic.
2. Sealed ducts means that they are diagnostically tested to have a leakage less than or equal to 6% of fan flow.
3. For electric baseboard heating, an HSPF of 3.41 or ACOP of 1.00 is input; for electric radiant panels, an HSPF of 3.55 or ACOP of 1.04 is entered.
4. For central air-conditioning heat pumps that are rated with a COP, assume the actual duct conditions and calculate the HSPF as 3.2 x COP - 2.4.

If the proposed design heating system does not have ducts, then there is no need to diagnostically test the ducts.

When no equipment has been specified at the time of the compliance run, minimum efficiencies are recommended to ensure that any equipment of minimum or higher efficiency may later be installed.

For equipment that is not certified, such as radiant heaters, the efficiency value modeled must be based on either manufacturers data or an approved calculation method.

If a house has multiple HVAC systems, but does not meet zonal control criteria, for compliance purposes, model one zone using a weighted average efficiency (based on floor area served by each system).

It is not always necessary to model supplemental heat. For example, if a bathroom has a supply duct from the main space conditioning system (typically gas-fired), you can ignore the electric space heating. If the room, however, does not have a supply vent from the main system, the supplemental electric resistance is the heat source for the space. In this latter case you must model two systems--the main system for the house and the electric system for the bathroom.

Cooling System Type H3

The cooling system for the standard design depends on the type of system specified for the proposed design. The difference between the proposed design system and the standard design system is an important factor in compliance. Table 5-5 shows the mapping between the proposed design cooling system and the standard design cooling system.

Table 5-5 – Cooling System Standard Design Map

Proposed Design System	***Standard Design System***
Split system central air conditioner with or without air distribution ducts Split system central heat pump with or without air distribution ducts No cooling system (Note 1) Water or air cooled chillers with fan coils or air handler	Split system air conditioner 10 SEER Diagnostic testing of refrigerant charge and airflow (Note 3) R-4.2 sealed ducts located in attic (Note 2)
Packaged central air conditioner with or without air distribution ducts Packaged central heat pump with or without air distribution ducts	Packaged air conditioner 9.7 SEER R-4.2 sealed ducts located in attic (Note 2)
Room heat pump (non-ducted, non-central heat pump) Room air conditioner (non-ducted, non-central air conditioners)	Non-ducted, non-central air conditioner of the same type. EER depends on unit type and size (see Table G-3) No air distribution ducts

Notes:

1. If no mechanical cooling is installed or the mechanical cooling is optional, a 10.0 SEER split system air conditioner is modeled for both the proposed and standard design with R-4.2 sealed ducts (6% leakage) located in the attic. The “non-cooling” system in the proposed design is assumed to have either a verified TXV or diagnostically tested refrigerant charge and airflow.
2. Sealed ducts means that they are diagnostically tested to have a leakage less than or equal to 6% of fan flow.
3. The requirement for diagnostic testing of refrigerant charge and airflow (or verification of a TXV) applies to climates 2, and 8 through 15 only.

If the proposed design cooling system does not have ducts, then there is no need for a HERS rater to diagnostically test the ducts.

For “non-cooling” systems, there is no need for a HERS rater to diagnostically test the refrigerant charge and airflow of the hypothetical air conditioner.

If air distribution ducts are installed for a heating only system in a house with no air conditioning and the ducts are not sealed, the proposed design cooling system modeled for compliance also must have non-sealed ducts. Thus, not sealing the ducts for a heating only system creates a compliance penalty not only for both heating but for cooling as well.

Cooling System Efficiency H4

Enter the Seasonal Energy Efficiency Ratio (SEER) for either air conditioners or heat pumps. For equipment not tested for SEER (e.g., greater than 65,000 Btu capacity), use the EER in place of SEER. Non-central cooling equipment have EER requirements as specified in the Glossary under EER.

5.4.9 Ducts

The Commission has approved algorithms and procedures for determining duct efficiency. These procedures are described in Chapter 4 and in Appendix J. When the proposed design has air distribution ducts (see Table 5-4 and Table 5-5), the ducts in the standard design are assumed to be sealed per the Package D prescriptive requirements, e.g. they are required to be diagnostically tested by a HERS rater as having a leakage less than or equal to 6% of the fan flow.

Ducts embedded in a concrete slab or in the ground beneath conditioned space are modeled as R-4.2 ducts in an attic. However, it is important to use insulation materials that are resistant to moisture and suitable for below grade application.

5.4.10 Water Heating

All computer inputs for water heating correspond to the variables explained in Chapter 6.

5.4.11 Unconditioned Space

The ability to model an unconditioned space in the building is an optional modeling capability of approved computer methods. Consult the compliance supplement for specific details on the types of unconditioned spaces and their modeling procedures.

Unconditioned Zone Characteristics K1

A computer method may have a variety of capabilities that can model one or more unconditioned spaces or "zones" adjacent to conditioned space. Enclosed, unheated areas such as sunspaces, unheated storage areas and crawl spaces may be modeled explicitly if the program is approved to accurately account for the thermal interactions between conditioned and unconditioned zones. Garages and conventional attic spaces may not be modeled as unconditioned zones.

Except for crawl space modeling explained under Section 5.4.12, **Controlled Ventilation Crawl Space**, the following general descriptions cover other types of unconditioned spaces that can be modeled for compliance as part of the proposed design. The number of unconditioned spaces that can be modeled is limited only by the capabilities of the approved computer method.

Exterior Walls, Doors, Roofs/Ceilings, and Floors K2

Surfaces that separate unconditioned space from the ambient (outdoor) temperature are considered "exterior." Surfaces that separate unheated space from heated space are treated differently as part of the Coupling to Conditioned Space (see K8).

The name, area, U-factor, orientation, tilt, absorptivity and slab characteristics of each opaque surface are input in essentially the same manner as for conditioned zones. See Section 5.4.2, **Walls, Doors, Roofs/Ceilings and Floors** for further information.

Fenestration K3

Fenestration attributes are the same as those relating to conditioned zones described in Section 5.4.3, **Fenestration**.

Shading K4

Shading characteristics are the same as those defined in Section 5.4.4, **Shading**.

Thermal Mass K5

Thermal mass inputs are generally the same as those described in Section 5.4.5, **Thermal Mass**. One exception is the amount of solar gain targeted to the mass surfaces. This "Absorbed Insolation Fraction" or "Solar Gain Distribution Factor" is automatically fixed at zero for conditioned space but is a restricted variable within an unconditioned space. See the program compliance supplement for further instructions.

Infiltration and Ventilation K6

The same rules apply as explained in Section 5.4.6, **Infiltration/Ventilation**.

Thermostat Setpoints K7

Thermostat setpoints are fixed by the program to ensure that no heating or cooling will occur.

Coupling to Conditioned Space K8

The thermal connection between conditioned and unconditioned spaces is divided into conductive and convective components. The conductive heat flow is a function of the U-factor and area of the surfaces that separate the zones. The convective coupling is defined according to the actual inlet and outlet area characteristics that define ventilation between the zones.

If mechanical ventilation is to be installed, the electrical energy use of the fan must be accounted for as defined in the computer method compliance supplement.

Figure 5-3 – Controlled Ventilation Crawl Space

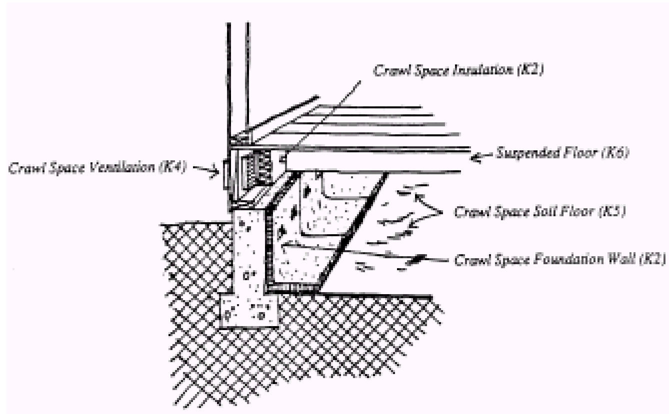


Table 5-6 – Crawl Space Soil Slab Heat Loss Rate (F2) Factor

	R-Value of Insulation						
Insulation Length Along Crawl Space Soil Floor (inches)	R-0	R-5	R-11	R-13	R-15	R-19	R-21
0	0.42	0.42	0.42	0.42	0.42	0.42	0.42
20	0.42	0.33	0.30	0.29	0.28	0.27	0.27
68	0.42	0.29	0.24	0.23	0.22	0.20	0.20

1. Based on ASHRAE Method of Calculating Transmission Heat Loss, 1989 ASHRAE Handbook of Fundamentals

5.4.12 Controlled Ventilation Crawl Space (CVC)

Crawl Space Model L1

A crawl space may be modeled as a separate unconditioned zone only when reduced crawl space vent areas are implemented. This approach is part of a Commission-approved exceptional method that establishes the crawl space soil as a type of slab with heat loss factors similar to the slab edge loss (F2) factors explained in input B11. Refer to Chapter 8, Section 8.6 for details on the requirements pertaining to installation of foundation wall insulation, drainage, ground water and soils, ventilation and crawl space ground cover.

Computer programs approved for modeling the crawl space automatically fix certain variables such as crawl space heat capacity (1.4 x suspended floor area), infiltration rate (0.22 air changes per hour), soil conductivity (0.60 Btu/hr-ft^2-ºF) and volumetric heat capacity (27 Btu/ft^3-ºF).

Crawl Space Foundation Wall L2

The foundation wall and insulation are modeled as it will be built including band joist area and the stem wall above and below outside grade level. The stem wall below the outside grade and above the crawl space grade may be considered a bermed wall and assumed to be fully shaded.

Crawl Space Volume L3

The average crawl space height from the ground to the bottom of the subfloor times the floor area above the crawl space, in cubic feet.

Crawl Space Ventilation L4

One half the actual total vent area shall be considered inlet area and one half outlet area. The crawl space ventilation area and type shall be shown on the plans and specifications.

Crawl Space Soil Floor L5

The crawl space soil floor is modeled as a four-inch thick mass element with its actual area. Slab edge losses are modeled according to the crawl space perimeter length and the slab heat loss rate (F2) factor from Table 5-6.

Suspended Floor L6

The suspended (raised) floor between the crawl space and conditioned space is modeled as built: actual area and U-factor (with indoor air films assumed for both sides of the surface).

5.4.13 Zonal Control

Zonal Control Features M1

Zonally controlled space heating and cooling systems must meet the eligibility requirements explained in Section 8.7. These systems must have a separate thermostat in the "living zone" and "sleeping zone" of the dwelling unit and a nonclosable opening area between the zones of 40 square feet or less.

A dwelling unit may meet zonal control eligibility requirements by having one or more individual HVAC units serving only the "Living" zone and one or more units serving only the "Sleeping" zone as an alternative to a single central HVAC unit with zonal control capabilities.

Approved computer programs model a zonally controlled system using certain built-in assumptions (see Figure 5-4):

- User-defined Living and Sleeping Zones, each with its own thermostat setpoints for heating, cooling and venting according to fixed occupancy schedules. These schedules include setback and setup temperatures for each zone throughout the day. (Each Living or Sleeping Zone created for modeling purposes may be comprised of one or more actual HVAC zones.)
- A U-factor of 0.293 is used for uninsulated wood frame walls between zones.
- A U-factor of 20.0 is used for nonclosable openings.
- Lightweight mass heat capacity proportioned according to each zone's percent of the total floor area.
- Internal gain distribution is 20,000 Btu + 15 Btu/ft^2 per day for the Living Zone and 15 Btu/ft^2 per day for the Sleeping Zone according to a fixed hourly schedule.

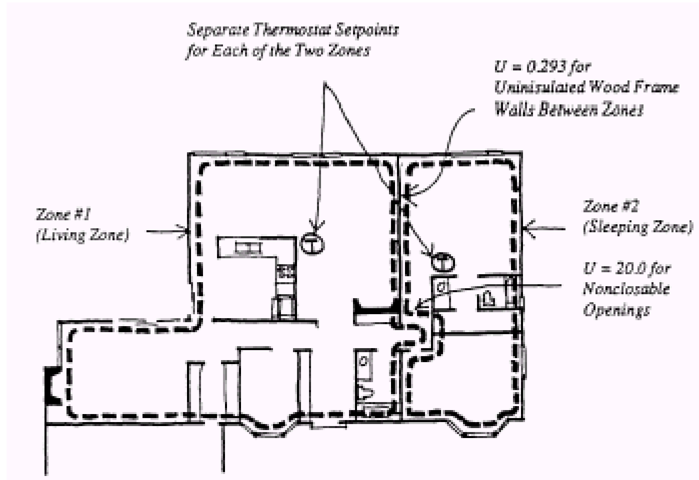
When cooling is not installed but is considered "optional", zonal credit for both heating and cooling systems can be taken as long as:

- All the zonal control criteria are met;
- The system is prepared for the cooling system (i.e., designed to be interconnected with the central furnace and with ducts sized for the air flow required for cooling);
- Common ducts are sized to handle the cooling air flow (cubic feet per minute);
- The location of the outdoor compressor is identified; and,
- The electrical panel is prepared to handle the load for a future air conditioner.

Variable Inputs M2

All physical attributes of the building are entered as part of either the Living Zone or Sleeping Zone according to the proposed building design. Fenestration and shading, walls, roofs/ceilings, floors, thermal mass and ventilation are all entered for each conditioned zone. The actual nonclosable area between zones is modeled, as well as the areas and U-factors of surfaces between zones.

Figure 5-4 – Zonal Control Modeling Assumptions



5.4.14 Radiant Barrier

Energy credit for radiant barrier installations is calculated with a modified ceiling U-factor and reduced attic temperatures that result in better HVAC distribution efficiencies for ducts in an attic below a radiant barrier.

Radiant barriers must meet specific eligibility and installation criteria as specified in Section 3.4. The radiant barrier and installation criteria will be listed on the CF-1R and C-2R as a Special Features and Modeling Assumptions.

Radiant Barriers N1

Installation of radiant barriers can improve building energy efficiency, particularly in hot climate zones. Radiant barriers are defined as fabric-type materials installed in the ceiling/roof assembly and having an emittance of 0.05 or less. To use the Commission-approved method of calculating the energy savings of radiant barriers, all installation and eligibility criteria listed in Section 3.4 must be met.

The radiant barrier energy credit is an adjustment to the ceiling U-factor allowed when the ceiling is adjacent to an attic with a radiant barrier. Consult the User's Manual for each approved computer method to determine required inputs for radiant barriers.

A radiant barrier credit is also available to account for the effects of radiant barriers on duct efficiency. This is described in Chapter 4 under duct efficiency.

5.4.15 Solar and Wood Stove Boiler Water Heating

All Inputs O1

All inputs for energy credit for use of solar or wood stove boiler-assisted water heating correspond to the variables explained in Chapter 6. Solar credit is provided through a Solar Fraction described in Chapter 6.

5.4.16 Combined Hydronic Space/Water Heating

All inputs for combined hydronic space and water heating correspond to the variables explained in Chapter 6.

5.4.17 Dedicated Hydronic Space Heating

Hydronic System Q1

A hydronic heating system is defined as one that has its space heating device(s), storage tank(s), distribution system and other components interconnected by common hot water piping. The Commission-approved method for calculating the overall efficiency of a hydronic space heating system is explained in Section 8.8. See Section 6.5 for information on combined hydronic space and water heating systems and how to calculate the energy use.

The Effective AFUE (minimum 0.80 AFUE) is obtained through that calculation method and input into the programs as the heating system efficiency with a Duct Efficiency Factor of 1.00 (ducts are assumed to be located in conditioned space). If pipes are located in unconditioned space the AFUE must be adjusted for pipe losses.

Solar water heating integrated into a combined hydronic system is explained in Section 6.3. Active Solar Space Heating is discussed in Section 5.4.19.

5.4.18 Building Additions

Various Inputs, Addition Alone R1

Internal gains are based on the fractional dwelling unit. The dwelling unit entry is determined by calculating:

$$\frac{\text{Addition}}{\text{Existing+Addition}}$$

Credit for zonal control is not allowed for an addition modeled alone.

Existing Plus Addition R2

All inputs are explained in Section 7.3.

5.4.19 Active Solar Space Heating

Active Solar Space Heating System S1

To determine the energy savings of an active solar space heating system, it is first necessary to obtain the total space heating load per month in order to enter those values into an approved version of the f-Chart program. Therefore, the monthly space heating load must be analyzed using an approved computer method so that the solar space contribution can be assessed.

Except for monthly space heating loads, all other values that are entered into f-Chart must be consistent with the fixed values listed in Section 6.3 and the actual active solar hot water system design.

Since building or dwelling unit monthly heating loads are not required as part of the standardized compliance reports (see Section 5.5), a special output report from the computer method may be needed. Consult the program compliance supplement for details.

5.5 Computer Method Documentation

5.5.1 Standard Reports

For consistency and ease of enforcement, the manner in which building features are reported by compliance computer programs is standardized. Commission approved computer programs must automatically produce compliance reports in this standard format. These standard reports are:

- Certificate of Compliance, CF-1R
- Computer Method Summary, C-2R

Both the CF-1R and the C-2R must have two highly visible sections, one for special features and modeling assumptions, and a second for features requiring verification by approved home energy rating system (HERS) raters. These two sections serve as "punchlists" for special consideration during compliance verification by the local building department and HERS rater. Items listed in the Special Features and Modeling Assumptions section indicate the compliance use of unusual features or assumptions, and that call for special care by the local building department. Items listed in the HERS Required Verification section are for features that rely on diagnostic testing and independent verification by approved HERS providers/raters to insure proper field installation. Diagnostic testing and verification by HERS providers/raters is in addition to local building department inspections.

Figure 5-5 illustrates the CF-1R and C-2R forms for sample buildings generated by an approved computer program.

5.5.2 Other Forms

Some additional forms that are required but may not be printed by the computer methods include:

- Mandatory Measures Checklist, MF-1R
- Installation Certificate, CF-6R
- Insulation Certificate, IC-1

Other forms and supporting documents may be applicable to a particular set of calculations:

- Construction Assembly U-factor, Form 3R
- Certificate of Field Verification and Diagnostic Testing, Form CF-4R

Figure 5-5 – Sample CF-1R and CF2-R Forms

```
CERTIFICATE OF COMPLIANCE: RESIDENTIAL                     Page 1         CF-1R
===============================================================================
Project Title.......... 1761sf 2001 Base                 Date..05/15/01 14:48:09
Project Address........ 123 Somewhere Street    *******  ---------------------
                        Cityville               *v6.01*  | _________________ |
Documentation Author... _________________________*******  | Building Permit # |
                        Sample User                      | _________________ |
                        123 Other Street                 | Plan Check / Date |
                        Othercity, CA 90000              | _________________ |
                        800-555-1212                     | Field Check/ Date |
Climate Zone........... 12                               ---------------------
Compliance Method...... XYZ Software
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM CF-1R         |
|                User#-Sample  User-Sample User     Run-Sample                |
-------------------------------------------------------------------------------

                              GENERAL INFORMATION
                              -------------------
           Conditioned Floor Area.....  1761 sf
           Building Type..............  Single Family Detached
           Construction Type .........  New
           Building Front Orientation.  Front Facing 90 deg (E)
           Number of Dwelling Units...  1
           Number of Stories..........  2
           Floor Construction Type....  Slab On Grade
           Glazing Percentage.........  16 % of floor area
           Average Glazing U-factor....  0.4 Btu/hr-sf-F
           Average Glazing SHGC.......  0.35
           Average Ceiling Height.....  8.9 ft

                           BUILDING SHELL INSULATION
                           -------------------------
Component     Frame  Cavity  Sheathing  Total  Assembly
  Type        Type   R-value  R-value  R-value U-factor Location/Comments
------------ ------- -------- -------- ------- ------- ------------------------
Wall          n/a     R-19     R-n/a    R-19     0.065 Right Wall
                                                       Front Wall, Left Wall
                                                       Back Wall
RoofRadiant   n/a     R-38     R-n/a    R-38     0.028 Attic Ceiling
Door          n/a     R-0      R-n/a    R-0      0.330 North Door
Floor         n/a     R-19     R-n/a    R-19     0.037 Garage Floor
SlabEdge      n/a     R-0      R-n/a          F2=0.760 Exposed Edge

                                  FENESTRATION
                                  ------------
                                                         Over-
                      Area    U-          Exterior       hang/
 Orientation          (sf)   Value  SHGC  Shading        Fins   Location/Comment
-------------------- ----- ------ ------  -------------- ----- ----------------
 Window   Right (N)    70.4  0.400  0.350 Standard        None
 Window   Front (E)    70.4  0.400  0.350 Standard        None
 Window   Left  (S)    70.4  0.400  0.350 Standard        None
 Window   Back  (W)    70.4  0.400  0.350 Standard        None
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

Project Title.......... 1761sf 2001 Base Date..05/15/01 14:48:09

| XYZ Software File-SAMPLE Wth-CTZ12S92 Program-FORM CF-1R |
| User#-Sample User-Sample User Run-Sample |

SLAB SURFACES

Slab Type	Area (sf)
Standard Slab	925

HVAC SYSTEMS

Equipment Type	Minimum Efficiency	Refrigerant Charge and Airflow	Duct Location	Duct R-value	Tested Duct Leakage	ACCA Manual D	Thermostat Type
Furnace	0.780 AFUE	n/a	Attic	R-4.2	Yes	No	Setback
ACSPLITTXV	10.00 SEER	Yes	Attic	R-4.2	Yes	No	Setback

DUCT TESTING DETAILS

Equipment Type	Duct Leakage Target (% fan CFM/CFM25)	Measured Supply Duct Surface Area (ft2)
Furnace / ACSPLITTXV	6% / 74.0	n/a

WATER HEATING SYSTEMS

Tank Type	Heater Type	Distribution Type	Number in System	Energy Factor	Tank Size (gal)	External Insulation R-value
Storage	Gas	Standard	1	0.60	50	R- n/a

SPECIAL FEATURES AND MODELING ASSUMPTIONS

*** Items in this section should be documented on the plans, ***
*** installed to manufacturer and CEC specifications, and ***
*** verified during plan check and field inspection. ***

This building incorporates a Radiant Barrier. The radiant barrier must be installed to cover all gable end walls and other vertical surfaces in the attic and attic ventilation criteria must be met.

This building incorporates Tested Duct Leakage.

Leaks in the air distribution system connections shall not be sealed with cloth backed rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
CERTIFICATE OF COMPLIANCE: RESIDENTIAL                    Page 3         CF-1R
===============================================================================
Project Title.......... 1761sf 2001 Base                Date..05/15/01 14:48:09
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM CF-1R         |
|                User#-Sample  User-Sample User     Run-Sample                 |
-------------------------------------------------------------------------------

                   SPECIAL FEATURES AND MODELING ASSUMPTIONS
                   -----------------------------------------

This building incorporates either Tested Refrigerant Charge and Airflow (RCA)
or a Thermostatic Expansion Valve (TXV) on the specified air conditioning
system(s).

                          HERS REQUIRED VERIFICATION
                          --------------------------
         *** Items in this section require field testing and/or    ***
         *** verification by a certified home energy rater under   ***
         *** the supervision of a CEC-approved HERS provider using ***
         *** CEC approved testing and/or verification methods.     ***

This building incorporates Tested Duct Leakage. Target CFM leakage
values measured at 25 pascals are shown in DUCT TESTING DETAILS above
or may be calculated as documented on the CF-6R. If the measured CFM
is above the target, then corrective action must be taken to reduce
the duct leakage and then must be retested. Alternatively, the
compliance calculations could be redone without duct testing.

Because a non-default duct configuration is specified,
leaks in the air distribution system connections shall not be sealed
with cloth backed rubber adhesive duct tapes unless such tape is used
in combination with mastic and drawbands.

This building incorporates either Tested Refrigerant Charge and Airflow (RCA)
or a Thermostatic Expansion Valve (TXV) on the specified air conditioning
system(s).
                                    REMARKS
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
CERTIFICATE OF COMPLIANCE: RESIDENTIAL                    Page 4        CF-1R
===============================================================================
Project Title.......... 1761sf 2001 Base                Date..05/15/01 14:48:09
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM CF-1R        |
|                User#-Sample  User-Sample User     Run-Sample                |
-------------------------------------------------------------------------------

                              COMPLIANCE STATEMENT
                              --------------------
  This certificate of compliance lists the building features and performance
  specifications  needed  to  comply with Title-24, Parts 1  and  6  of  the
  California  Code  of Regulations, and the  administrative  regulations  to
  implement them.  This certificate has been signed by the  individual  with
  overall  design  responsibility. When this certificate of  compliance  is
  submitted for a single building plan to be built in multiple orientations,
  any  shading feature that is varied is indicated in  the  Special Features
  Modeling Assumptions section.

           DESIGNER or OWNER                    DOCUMENTATION AUTHOR

  Name.... Bill Designer                Name.... ________________________________
  Company. Builder                      Company. Sample User
  Address. 123 Other Street             Address. 123 Other Street
           Othercity, CA 90000                    Othercity, CA 90000
  Phone... 800-555-1212                 Phone... 800-555-1212
  License. _________________________

  Signed.. _________________________    Signed.. _________________________
                             (date)                                (date)

           ENFORCEMENT AGENCY

  Name.... _________________________
  Title... _________________________
  Agency.. _________________________
           _________________________
  Phone... _________________________

  Signed.. _________________________
                             (date)
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
COMPUTER METHOD SUMMARY                                    Page 1          C-2R
===============================================================================
Project Title.......... 1761sf 2001 Base                 Date..05/15/01 14:48:09
Project Address........ 123 Somewhere Street     *******  ---------------------
                        Cityville                *v6.01*  | _________________ |
Documentation Author... _________________________*******  | Building Permit # |
                        Sample User                       | _________________ |
                        123 Other Street                  | Plan Check / Date |
                        Othercity, CA 90000               | _________________ |
                        800-555-1212                      | Field Check/ Date |
Climate Zone........... 12                                ---------------------
Compliance Method...... XYZ Software
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM C-2R         |
|             User#-Sample  User-Sample User     Run-Sample                    |
-------------------------------------------------------------------------------

       =================================================================
       =                 Generic XYZ ENERGY USE SUMMARY                  =
       =                 ----------------------------                  =
       =  Energy Use                Standard    Proposed   Compliance  =
       =  (kBtu/sf-yr)                Design      Design     Margin    =
       =  -----------------------  ----------  ----------  ----------  =
       =  Space Heating..........     17.50       14.95        2.55    =
       =  Space Cooling..........      6.59        5.58        1.01    =
       =  Water Heating..........     14.15       12.31        1.84    =
       =                            --------    --------    --------   =
       =                  Total     38.24       32.84        5.40    =
       =                                                               =
       =     *** Building complies with Computer Performance ***       =
       =================================================================

                           GENERAL INFORMATION
                           -------------------
             Conditioned Floor Area.....  1761 sf
             Building Type.............  Single Family Detached
             Construction Type .........  New
             Building Front Orientation.  Front Facing 90 deg (E)
             Number of Dwelling Units...  1
             Number of Building Stories.  2
             Weather Data Type.........  Fullyear

             Floor Construction Type....  Slab On Grade
             Number of Building Zones...  1
             Conditioned Volume.........  15588 cf
             Slab-On-Grade Area.........  925 sf
             Glazing Percentage.........  16 % of floor area
             Average Glazing U-factor....  0.4 Btu/hr-sf-F
             Average Glazing SHGC.......  0.35
             Average Ceiling Height.....  8.9 ft
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
COMPUTER METHOD SUMMARY                                    Page 2          C-2R
===============================================================================
Project Title.......... 1761sf 2001 Base                 Date..05/15/01 14:48:09
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM C-2R          |
|                User#-Sample  User-Sample User     Run-Sample                 |
-------------------------------------------------------------------------------

                           BUILDING ZONE INFORMATION
                           -------------------------
               Floor         # of                        Vent   Vent      Air
               Area  Volume  Dwell  Cond-  Thermostat  Height  Area    Leakage
Zone Type      (sf)   (cf)   Units itioned    Type      (ft)   (sf)    Credit
-------------- ----- ------- ----- ------- ----------- ----- -------- ---------
HOUSE
 Residence      1761  15588   1.00   Yes   Setback       8.0 Standard   No

                                OPAQUE SURFACES
                                ---------------
                Area   U-   Insul Act      Solar    Form 3       Location/
Surface         (sf)  value R-val Azm Tilt Gains  Reference      Comments
-------------- ------ ----- ----- --- ---- ----- ------------ ----------------
HOUSE
 1 Wall          358  0.065 19      0    90 Yes  None         Right Wall
 2 Wall          398  0.065 19     90    90 Yes  None         Front Wall
 3 Wall          398  0.065 19    180    90 Yes  None         Left Wall
 4 Wall          398  0.065 19    270    90 Yes  None         Back Wall
 5 RoofRadiant  1261  0.028 38    n/a     0 Yes  None         Attic Ceiling
 6 Door           40  0.330 0       0    90 Yes  None         North Door
 7 Floor         286  0.037 19    n/a     0 No   None         Garage Floor

                                PERIMETER LOSSES
                                ----------------
                   Length    F2      Insul  Solar
      Surface       (ft)   Factor   R-val  Gains Location/Comments
      ------------ ------ -------- ------- ----- ---------------------
      HOUSE
       8 SlabEdge    124    0.760  R-0       No  Exposed Edge

                             FENESTRATION SURFACES
                             ---------------------
                        Area   U-        Act      Exterior Shade
Orientation             (sf) Value SHGC  Azm Tilt Type/SHGC      Location/Comment
---------------------- ----- ----- ----- --- ---- -------------- --------------
HOUSE
 1 Window   Right (N)   70.4 0.400 0.350   0  90  Standard/0.76
 2 Window   Front (E)   70.4 0.400 0.350  90  90  Standard/0.76
 3 Window   Left  (S)   70.4 0.400 0.350 180  90  Standard/0.76
 4 Window   Back  (W)   70.4 0.400 0.350 270  90  Standard/0.76
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
COMPUTER METHOD SUMMARY                                    Page 3          C-2R
===============================================================================
Project Title.......... 1761sf 2001 Base                Date..05/15/01 14:48:09
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM C-2R          |
|                User#-Sample  User-Sample User     Run-Sample                |
-------------------------------------------------------------------------------

                                SLAB SURFACES
                                -------------
                                             Area
                             Slab Type       (sf)
                             ---------------- ------
                             HOUSE
                                Standard Slab   925

                                 HVAC SYSTEMS
                                 ------------
                         Refrigerant                     Tested     ACCA
  System       Minimum   Charge and   Duct       Duct     Duct     Manual  Duct
   Type       Efficiency  Airflow   Location    R-value  Leakage     D     Eff
------------- ----------- ------- ------------- ------- --------- -------- ----
HOUSE
 Furnace       0.780 AFUE   n/a    Attic          R-4.2    Yes      No    0.848
 ACSPLITTXV    10.00 SEER   Yes    Attic          R-4.2    Yes      No    0.796

                             DUCT TESTING DETAILS
                             --------------------
                                   Duct         Measured Supply
                              Leakage Target   Duct Surface Area
      Equipment Type         (% fan CFM/CFM25)       (ft2)
      ------------------------ ------------------ -----------------
      HOUSE
       Furnace / ACSPLITTXV           6% /   74.0       n/a

                            WATER HEATING SYSTEMS
                            ---------------------
                                              Number          Tank   External
                                                in    Energy  Size   Insulation
 Tank Type     Heater Type  Distribution Type System  Factor  (gal)  R-value
 ------------ ----------- ------------------- ------ -------- ------ ----------
  1 Storage   Gas         Standard               1     0.60     50     R- n/a

                  SPECIAL FEATURES AND MODELING ASSUMPTIONS
                  -----------------------------------------
       *** Items in this section should be documented on the plans, ***
       *** installed to manufacturer and CEC specifications, and    ***
       *** verified during plan check and field inspection.         ***

This building incorporates a Radiant Barrier. The radiant barrier must be
installed to cover all gable end walls and other vertical surfaces in the attic
and attic ventilation criteria must be met.

This building incorporates Tested Duct Leakage.

Because a non-default duct configuration is specified,
leaks in the air distribution system connections shall not be sealed
with cloth backed rubber adhesive duct tapes unless such tape is used
```

Figure 5-5 – Sample CF-1R and CF2-R Forms (continued)

```
COMPUTER METHOD SUMMARY                                    Page 4          C-2R
===============================================================================
Project Title.......... 1761sf 2001 Base                Date..05/15/01 14:48:09
===============================================================================
|      XYZ Software  File-SAMPLE  Wth-CTZ12S92  Program-FORM C-2R         |
|                User#-Sample  User-Sample User     Run-Sample                |
-------------------------------------------------------------------------------

                   SPECIAL FEATURES AND MODELING ASSUMPTIONS
                   -----------------------------------------
in combination with mastic and drawbands.

This building incorporates either Tested Refrigerant Charge and Airflow (RCA)
or a Thermostatic Expansion Valve (TXV) on the specified air conditioning
system(s).

                          HERS REQUIRED VERIFICATION
                          --------------------------
         *** Items in this section require field testing and/or    ***
         *** verification by a certified home energy rater under   ***
         *** the supervision of a CEC-approved HERS provider using ***
         *** CEC approved testing and/or verification methods.     ***

This building incorporates Tested Duct Leakage. Target CFM leakage
values measured at 25 pascals are shown in DUCT TESTING DETAILS above
or may be calculated as documented on the CF-6R. If the measured CFM
is above the target, then corrective action must be taken to reduce
the duct leakage and then must be retested. Alternatively, the
compliance calculations could be redone without duct testing.

Because a non-default duct configuration is specified,
leaks in the air distribution system connections shall not be sealed
with cloth backed rubber adhesive duct tapes unless such tape is used
in combination with mastic and drawbands.

This building incorporates either Tested Refrigerant Charge and Airflow (RCA)
or a Thermostatic Expansion Valve (TXV) on the specified air conditioning
system(s).
                                    REMARKS
_______________________________________________________________________________
_______________________________________________________________________________
```

5.6 Standard Design Assumptions

Each approved computer method must automatically calculate the energy budget for the standard design (see Section 5.2). This feature of the computer method must define the custom budget or Standard Design run based upon data entered for the Proposed Design using all the correct fixed and restricted inputs. These inputs cannot be altered in the Proposed Design except as specified in Section 5.4 or the computer method compliance supplement.

The computer method defines the standard design by modifying the geometry of the Proposed Design and inserting the building features of Package D as specified in the *Standards*. This process is built into each approved computer method (ACM) and the user cannot access it. Key details on how the standard design is created and calculated by the computer methods, including the listing of fixed and restricted input assumptions, is available in the latest edition of the Commission's **Residential Alternative Calculation Methods Approval Manual,** Standard Design: General Approach.

The basis of the standard design is Package D, contained in Table 3-1.

The standard design assumes the same total conditioned floor area, conditioned slab floor area, and volume as the proposed design, and the same gross exterior wall area as the proposed design, except that the wall area in each of the four cardinal orientations is equal. The standard design uses the same roof/ceiling area, raised floor area, slab-on-grade area and perimeter as the proposed design, assuming the standard insulation R-values required in the prescriptive packages.

Total fenestration area is determined by the package specification and evenly distributed between the four cardinal orientations. Solar heat gain coefficients are those listed in Packages D, and no fixed shading devices such as overhangs are assumed.

The standard design includes minimum efficiency heating and cooling equipment, as well as the minimum duct R-value with ducts in a vented attic and tested duct leakage. Assumptions for refrigerant charge and airflow are those listed in Package D. The water heating system of the standard design is assumed to be equal to the water heating energy budget (explained in Chapter 6).

6 Water Heating Calculations

This chapter explains the relationship of water heating energy to the overall *Energy Efficiency Standards* (*Standards*) compliance for a building. The Introduction briefly summarizes the *Water Heating Calculation Method* and explains when calculations and forms are required. This is followed by a more detailed discussion of the Basic Approach to the Method and step-by-step instructions on how to complete the water heating forms. Case studies outline the requirements for common and unusual water heating systems. Separate calculations and forms are explained for hydronic space and water heating systems. The chapter concludes with detailed descriptions of system components and installation criteria.

6.1 Introduction

Water heating energy use is important because it accounts for about a quarter of residential energy consumption, as illustrated in Figure 6-1. This is the same percentage used statewide for residential space heating, and six times the amount used for residential cooling. Water heating energy may be an even higher percentage of the total energy consumption in small residences with lower space heating and cooling requirements.

Figure 6-2 shows the general flow of energy from the fuel source through the water heating system to the end use in the building. *Total energy in* is a combination of source energy plus any auxiliary inputs, which equals total energy out. *Total energy out* includes energy lost through electric power generation and transmission to the residence, water heater recovery efficiency and standby loss, distribution system losses and finally, hot water delivered to fixtures and appliances (see *Source Energy* in the *Glossary*).

Figure 6-1 – Largest Residential Energy End

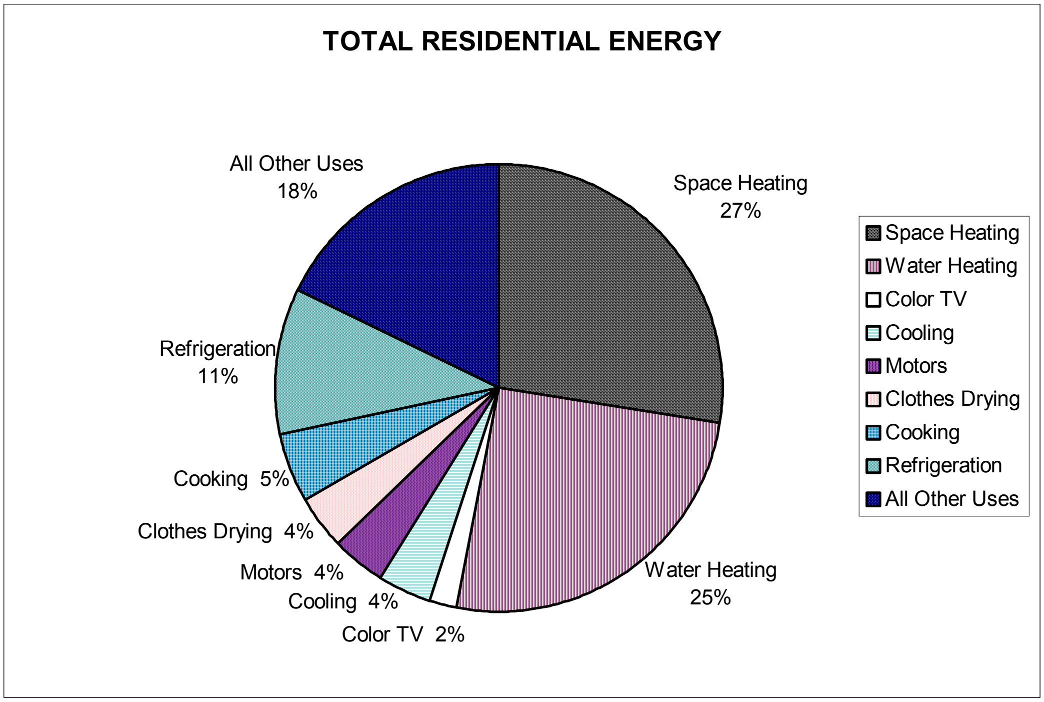
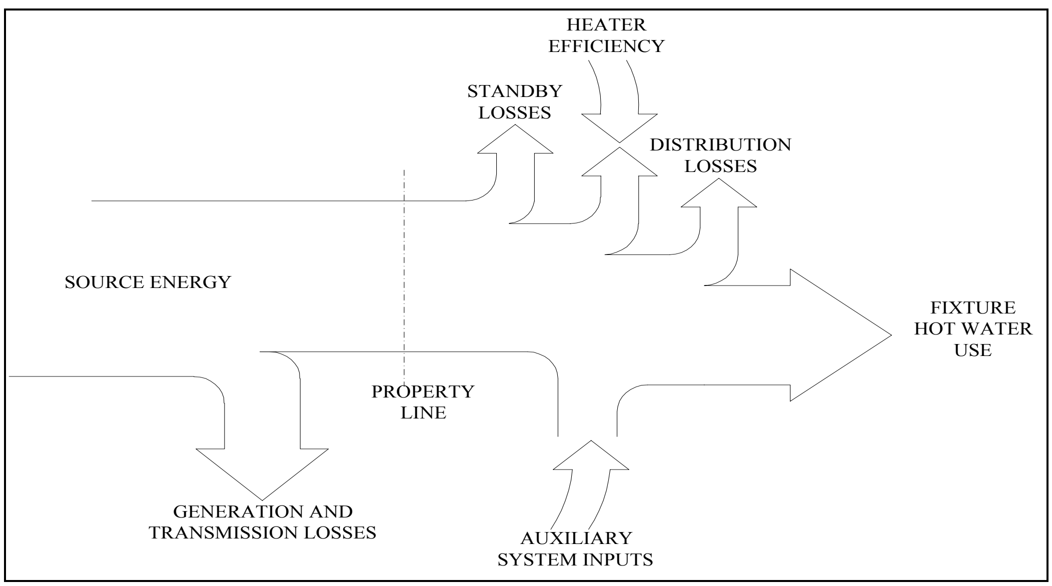


Figure 6-2 – Water Heater System Energy Flow Diagram



Energy Factor is a measure used for *Heater Efficiency* for most water heaters used in single family dwellings and includes standby losses, recovery efficiency (the ratio of energy output used to heat the water divided by energy input), and the tank volume. More efficient water heaters have a higher EF.

Standby Loss accounts for energy lost while storing heated water. It includes heat losses through the water heater tank walls, fittings and flue, if any, plus any pilot light energy. Standby loss depends on the design and insulation of the water heater, as well as the difference between the temperature of the water and that of the air around the tank. Water heating energy use can be reduced by decreasing standby loss. This can be done by selecting a more efficient heater.

The water heater efficiency rating for small water heaters used in the water heating calculation method is the ***Energy Factor*** (EF) which combines tank volume, internal insulation, recovery efficiency and standby loss. The higher the EF the more efficient the water heater.

Recovery energy is the energy used to heat water, including the inefficiency (or efficiency loss) of the heater.

Recovery load is the amount of energy in hot water that the water heater needs to provide. It includes only the energy in the hot water that is used by the building occupant and the distribution losses.

Standby loss is over a quarter of a gas storage type water heater system's total energy use. When the system fuel is natural gas, there are no generation or transmission losses as are associated with electricity. Fuel type is very important in determining water heating energy use. While natural gas, LPG or oil can be burned directly to heat water, electricity is typically generated in a power plant far from the residence and then transmitted over power lines to the final end use. Approximately two thirds of the source energy used to generate electricity is lost in this process.

Any electric water heating system must automatically account for the inefficiency of the fuel type. Standard electric water heaters are not considered energy efficient for this reason.

Electric heat pump water heaters, however, are closer to the efficiency of typical gas systems, because they use the outdoor air as a heat source in heating water (see *Heat Pump* in the *Glossary*).

See Table 6-1A and Section 6.6 for more information on water heater types.

All water heating systems must meet the mandatory measures explained in Chapter 2, and all water heaters installed in California must be certified to the Commission (see Section 2.6 and 1.6). Several values that are needed in the water heating method are listed in this directory.

6.1.1 Water Heating Calculation Method Compliance/ Plan Check

The water heating calculation method estimates the amount of source energy used by any water heating system (the *Proposed Energy Use*) and compares it to the energy budget for water heating established by the *Standards* (the *Standard Energy Use*).

Sections 6.2 and 6.3 give detailed information and instructions on using the water heating calculation method. Section 6.3 includes blank copies of the various forms and the tables used in the calculations.

The calculation method looks at three components of each water heating system:

- Water Heater Type
- Auxiliary Input (nondepletable energy sources)
- Distribution System Type

Water Heater Type

Water heater types that can be analyzed using the water heating calculation method are:

- Standard Water Heater
- Storage Gas
- Large Storage Gas
- Storage Electric
- Storage Heat Pump

- Instantaneous Gas
- Instantaneous Electric
- Indirect Gas
- Oil-Fired

See Table 6-1A for brief descriptions of each water heater type and Section 6.6 for more detailed descriptions plus installation criteria.

Auxiliary Inputs

Auxiliary inputs are other energy sources that contribute to overall water heating. The calculation method allows water heating credits for two auxiliary input types that save energy by using nondepletable energy sources:

- Passive and Active Solar Water Heaters
- Wood Stove Boilers

See Table 6-1B for brief descriptions of each auxiliary input type and Section 6.6 for more detailed descriptions plus installation criteria.

Table 6-1A – Summary of System Components: Water Heaters

Water Heaters and Related Components	***Description***
Standard Water Heaters	Storage gas water heaters, 50 gallons or less (R-12 external insulation is a mandatory requirement for any water heater with an EF of less than 0.58).
Storage Gas	A gas water heater with a storage capacity of two gallons or more and a rated input of 75,000 Btu/hr or less.
Large Storage Gas	A storage gas water heater with greater than 75,000 Btuh input.
Storage Electric	An electric water heater with a storage capacity of two gallons or more.
Storage Heat Pump	An electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water.
Instantaneous Gas	A gas water heater that heats water on demand rather than storing preheated water in a tank. Manufacturer's specified storage capacity must be less than two gallons.
Instantaneous Electric	An electric water heater that heats water on demand rather than storing preheated water in a tank. Manufacturer's specified storage capacity must be less than two gallons.
Indirect Gas	A water heater consisting of a storage tank with no heating elements or combustion devices, connected via piping and recirculating pump to a heat source typically consisting of a gas or oil fired boiler.

Table 6-1B – System Component Descriptions: Auxiliary Inputs

Auxiliary Systems	***Description***
Passive Solar Water Heaters	Systems which collect and store solar thermal energy for domestic water heating applications and do not require electricity to recirculate water through a solar collector.
Active Solar Water Heaters	Systems which collect and store solar thermal energy for domestic water heating applications requiring electricity to operate pumps or other components.
Wood Stove Boilers	Wood stoves equipped with heat exchangers for heating domestic hot water (see Figure 6-3).

Distribution System

The water heating *distribution system* is the configuration of piping, pumps and controls which regulates delivery of hot water from the water heater to all end uses within the building. The water heating method gives credits for especially energy-efficient distribution systems, such as non-recirculating systems with pipe insulation, while assigning penalties for less energy-efficient systems, such as continuous recirculation systems with no controls.

Distribution systems that may be analyzed are:

- Standard Distribution System
- Point of Use
- Hot Water Recovery
- Pipe Insulation
- Parallel Piping
- Recirculation: Continuous
- Recirculation: Temperature Controlled
- Recirculation: Time Controlled
- Recirculation: Time & Temperature Controlled
- Recirculation: Demand Pumping
- Combined Credits

Table 6-1C gives brief definitions of all of the distribution system types listed above, while Section 6.6 describes the systems in more detail and explains any required installation criteria.

When are Water Heating Forms Required?

Water heating forms must be provided only for non-standard systems that are not listed in Chapter 3 (for Prescriptive Packages). Table 6-2 summarizes when water-heating forms are required within the different compliance approaches.

Standard Water Heating Systems

If a proposed water heating system in a single family residence has no more than one *standard water heater* (as defined below) with a *standard distribution system*, then the water heating system need not be analyzed, but may be assumed to meet the water heating energy budget without requiring any additional forms or calculations. Compliance is demonstrated by simply listing the water heater on the Certificate of Compliance (CF-1R) Form.

The following water heater type is considered a *standard water heater:* storage gas water heater, 50 gallons or less, with a standard distribution system.

Note: Any storage heat pump water heater, 50 gallons or less, with an EF of at least 1.8 in Climate Zones 1-15, or at least 2.6 in Climate Zone 16, and a standard distribution system meets the water heating energy budget.

Table 6-1C – System Component Descriptions: Distribution Systems

Distribution Systems	***Description***
Standard	Standard system without any pumps for distributing hot water
Point of Use	System with no more than 8 feet horizontal distance between the water heater and hot water fixtures, except laundry. (Not used with central systems in multi-family buildings.)
Hot Water Recovery	System which reclaims hot water from the distribution piping by drawing it back to the water heater or other insulated storage tank. (Not used with central systems in multi-family buildings.)
Pipe Insulation	R-4 (or greater) insulation applied to 3/4 inch or larger, non-recirculating hot water mains in addition to insulation required by the *Standards*, §150(j) (first five feet from water heater on both hot and cold water pipes).
Parallel Piping	Individual pipes from the water heater to each point of use.
Recirculation: Continuous	Distribution system using a pump to recirculate hot water to branch piping though a looped hot water main with no control of the pump, such that water flow is continuous. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Temperature	Recirculation system that uses temperature controls to cycle pump operation to maintain recirculated water temperatures within certain limits. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Time	Recirculation system that uses a timer control to cycle pump operation based on time of day. (Not used with instantaneous water heaters or with central systems in multi-family buildings.) Pipe insulation is required.
Recirculation: Time/Temp	Recirculation system that uses both temperature and timer controls to regulate pump operation. (Not used with instantaneous water heaters or with central systems in multi-family buildings.) Pipe insulation is required.
Recirculation: Demand	Recirculation system that uses brief pump operation to recirculate hot water to fixtures just prior to hot water use when a demand for hot water is indicated. (Not used with instantaneous water heaters or with central systems in multi-family buildings.)
Recirculation/Demand w/ Hot Water Recovery	Combined system consisting of Recirculation: Demand and Hot Water Recovery (Not used with instantaneous water heaters or with central systems in multi-family buildings).
Recirculation/Demand w/ Pipe Insulation	Combined system consisting of Recirculation: Demand and Pipe Insulation (Not used with instantaneous water heaters or with central systems in multi-family buildings).

A *standard distribution system* is one which does not incorporate a pump to recirculate hot water, and does not take credit for any special design features. A distribution system normally eligible for energy credits, such as one with pipe insulation, may be modeled as standard (i.e., no credits) to avoid water heating calculations.

See Section 6.6 for more detailed descriptions of standard water heaters and distribution systems, including installation criteria.

Table 6-2 – When Are Water Heating Forms Required?

	Water Heating System Type		
Compliance Method	Standard	Pre-Calculated Non-Standard	Other Non-Standard
Prescriptive Packages	No	No [1,2]	Yes [4]
Performance Method [4]	No	n/a	No [3,4]

Notes:

1 No water heating forms are required, except to document solar collector systems and/or wood stoves.

2 Pre-calculated non-standard systems are listed in Chapter 3.

3 Approved programs perform water heating calculations internally for most systems; forms need not be submitted unless the system type is not modeled by the approved program.

4.See Table 6-3 and Table 6-4 for a summary of water heating forms and compliance scenarios

Pre-Calculated Non-Standard Systems

To simplify compliance with the prescriptive packages the Commission has developed lists of non-standard water heating systems that may be used without submitting water heating calculations.

Systems pre-calculated and shown to meet or exceed the efficiency of a standard system are found in Table 3-14 through Table 3-18.

Approved Computer Methods

Approved computer programs perform water heating calculations internally, making water heating compliance forms unnecessary. However, other documentation may be required to support water heating credits for auxiliary inputs or other unique system components used for compliance.

Water Heating Calculations And Energy Compliance

The basic structure of the water heating calculation method is to:

(1) Calculate the *Proposed Energy Use* of the proposed water heating system

(2) Determine the *Standard Energy Use* (the energy budget)

(3) Compare the *Proposed Energy Use* to the *Standard Energy Use*

Prescriptive Packages

When demonstrating energy compliance for a building using the Prescriptive Packages, the proposed energy use for a water heating system must be less than the standard energy budget (Section 3.7). This requirement may be met by:

- Installing a standard water heating system;
- Installing an approved non-standard system as listed in Table 3-14 through Table 3-18; or,
- Completing the calculations and forms contained in Section 6.3 to verify that the proposed energy use is less than the standard energy use.

Performance Methods

When demonstrating energy compliance for a building using an approved performance method, the building's total (combined) space conditioning and water heating energy consumption cannot exceed the sum of the total space conditioning and water heating energy budgets. See Section 5.2.

When using an approved computer program, water heating compliance is calculated internally within the program.

If the building has a standard water heating system as defined above, the Proposed Energy Use is equal to the Standard Energy Use in the performance methods.

Water Heating Calculations For Additions

There are three typical situations for water heating systems in building additions:

1. The addition uses the existing water heating system. No new water heater is added. If no new water heater is added, the addition may be analyzed by itself without requiring water heating calculations. If the addition is analyzed using the existing-plus-addition method (performance), then either the existing water heating system may be modeled as is or it may be assumed to be a standard water heating system (see Section 6.3 - use the same modeling assumptions for all calculations).
2. A new water heater, installed to replace the existing water heater, serves the entire existing building plus the addition, and there is no increase in the number of water heaters in the building. In this case water heating calculations are not required because the total number of water heaters does not increase. The new water heater serves as a replacement; for the purpose of compliance analysis, it may be assumed to be a standard water heater.
3. A new water heater (or heaters) is added with the addition, resulting in an increase in the number of water heaters (see below).

6.1.2 Additions that Increase the Total Number of Water Heaters

§ 152(a), Exception No. 3

If the addition will increase the total number of water heaters in the building, one of the following types of water heaters may be installed to comply with Section 152(a)1. or Section 152(a)2.A, and Section 152 (c):

(1) A gas storage non-recirculating water heating system that does not exceed 50 gallons capacity; or

(2) If no natural gas is connected to the building, an electric storage water heater that does not exceed 50 gallons capacity, has an energy factor not less than 0.90; or

(3) A water heating system determined by the Executive Director to use no more energy than the one specified in (1) above; or if no natural gas is connected to the building, a water heating system determined by the Executive Director to use no more energy than the one specified in (2) above.

For prescriptive compliance with Section 152(a)1., the water heating systems requirement in Section 151(f)8. shall not apply. For performance compliance for the addition alone, only the space conditioning budgets of Section 151(b)2. shall be used; the water heating budgets of Section 151(b)1. shall not apply.

The performance approach for the existing building and the addition in Section 152(a)2.B may be used to show compliance, regardless of the type of water heater installed.

When there is an increase in the number of water heaters, the addition may be analyzed using any of the compliance approaches under certain conditions. Addition alone compliance may be used if:

(a) The additional water heater is either a 50 gallon or less, gas storage, nonrecirculating water heater or equivalent (see Section 7.2.4) that also meets the mandatory requirements (see Chapter 2);

(b) The home does not have natural gas available and the additional water heater is either a 50-gallon or less electric water heater with an EF of 0.90 or greater or equivalent (see Section7.2.4);

(c) If the conditions in (a) or (b) are met, water heating calculations are not required with any of the compliance approaches, and no credit or penalty is allowed. Computer compliance calculations will show proposed energy use for water heating to be equal to standard energy use.

Existing-plus-addition compliance may be used when a new water heating system is proposed which is not described in (a) and (b) above, is not found in Section 7.2.4, or to take credit for a more efficient water heating system.

See Examples 6-7 and 6-10 in Section 6.4, and Chapter 7 for more information on compliance of water heaters associated with additions.

6.1.3 Water Heating Inspection

Check that the number and types of water heater systems installed, as indicated on the CF-6R and check to see that this corresponds to the approved CF-1R. The distribution system is also significant and must correspond to plan specifications. For example:

- If the plans indicate the presence of a hot water recovery system, it must be installed.
- If a recirculation system is installed, verify that it was accounted for in the compliance documentation (CF-1R) and check for any required controls (e.g., demand pump, timer).
- If a point of use credit is specified, the water heater must be no further than 8 feet from all hot water outlets (excluding washing machines).

Table 6-6 below shows the different distribution system types and credits or penalties for each distribution system. Penalties are negative values in this table.

Verify the make and model number of the installed water heater unit matches that listed on the Installation Certificate (CF-6R).

If the water heater has an EF of less than 0.58, an R-12 water heater blanket is required (internal insulation cannot be used to satisfy this mandatory requirement). For water heaters with 0.58 EF or higher, no insulation blanket is required. The blanket should be securely attached around the water heater. The top of the water heater should not be insulated and a cutout in the blanket should be provided for combustion air intake.

6.2 Basic Approach

§151(b)1

Water heating budgets. The budgets for water heating systems are those calculated from:

Equation 6-2

EQUATION 1-N—ANNUAL WATER HEATING BUDGET (AWB):

For dwelling units less than 2500 ft²:

$$AWB\ (kBtu/yr.\text{-}ft^2) = \frac{16370}{CFA} + 4.85$$

For dwelling units equal to or greater than 2500 ft²:

$$AWB\ (kBtu/yr.\text{-}ft^2) = \frac{(26125)}{CFA}$$

Where CFA = the building's conditioned floor area in square feet.

The annual water heating budget calculated from Equation No. 1-N may be met by either:

A. Calculating the energy consumption of the proposed water heating system using an approved calculation method without an external insulation wrap or

B. Installing any gas storage type non-recirculating water heating system that does not exceed 50 gallons of capacity, and that meets the minimum standards specified in the Appliance Efficiency Standards.

Note: Storage gas water heaters with an energy factor of less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater in accordance with §150(j).

As outlined in Section 6.1, the water heating method involves the calculation of the *Proposed Energy Use* of the proposed system, and the determination of the *Standard Energy Use* for the dwelling unit being analyzed (see form DHW-1).

The standard water heating energy use per dwelling unit is dependent on the total conditioned floor area of the dwelling unit. Allowable water heating energy use per dwelling unit increases with an increase in floor area. However, 26,125 kBtu/yr-unit is the maximum standard water heating energy use for dwelling units larger than 2,500 square feet (§151(b)1 of the *Standards*).

Standard energy use is assumed to be climate-independent. It is based on the energy use of a federally rated minimum efficiency 50 gallon gas water heater (EF 0.525) with a standard distribution system (see Section 6.6).

Presented as a hand method in this chapter, water heating calculations use a series of forms and tables included at the end of Section 6.3. The forms and tables used are selected according to the specific proposed water heating system. Table 6-3 and Table 6-4 summarize the forms as well as their application in a range of compliance situations.

The water heating method can be used to analyze water heating energy use of:

- A specific single dwelling unit;
- An average dwelling unit in a multi-family building; or,
- Each different dwelling unit in a multi-family building.

Note: When multi-family water heaters are *shared* by more than one dwelling unit, compliance must be based on the average of the square feet of the dwelling units served by each (different) shared water heater.

Table 6-3 – Summary of Water Heating Forms

Number	***Name/Function***	***Application***
DHW-1	Water Heating Worksheet	Non-standard water heating system
DHW-2A	Water Heating for Single Family w/ Multiple Heaters	Single-family dwelling unit with more than one water heater
DHW-2B	Water Heating for Multi-Family	Multi-family building
DHW-3	Large or Indirect Water Heater	Large Storage Gas or Indirect Gas heater Worksheet(see Section 6.6)
DHW-4	Removed (incorporated into DHW-1)	Solar and wood heating calculations
DHW-5	Combined Hydronic Space and Water Heating	Hydronic system serving both space heating and water heating (see Section 6.5)

Table 6-4 – Summary of Compliance Scenarios

Compliance Scenario		***Forms Submitted***
a.	One Standard System Per Dwelling Unit	None
b.	Pre-Calculated System (see Chapter 3)	None
c.	One Non-standard System Per Dwelling Unit(other than pre-calculated systems)	DHW-1
d.	Single Family Dwelling w/Multiple Heaters(other than pre-calculated systems)	DHW-1, DHW-2A
e.	Multi-Family Building	DHW-1, DHW-2B
f.	Solar or Wood Stove (Auxiliary Input)	DHW-1
g.	Combined Hydronic Space and Water Heating	DHW-5
h.	Additions (see Chapter 7)	Same as a, b, c, d, e, f or g above

The compliance methodology has three steps:

1. Determine the *Adjusted Recovery Load* to be satisfied by the water heating system. The *Standard Recovery Load* (from Table 6-5) may be modified by *distribution piping system credits or penalties* (from Table 6-6 or Table 6-7) and/or a *solar energy credit* (from DHW-1).
2. Determine the *Proposed Energy Use* of the water heating system. The *Basic Energy Use* (from Table 6-8A through D according to heater type) may be modified by a *wood stove boiler credit* (from DHW-1).
3. Determine the *Standard Energy Use* of the dwelling unit(s) (from Table 6-5).

Water heating compliance depends on a comparison of the Proposed Energy Use and the Standard Energy Use:

- Prescriptive: The Proposed Energy Use must be less than or equal to the Standard Energy Use for compliance of the water heating system.
- Performance Methods: The difference between Proposed and Standard Water Heating Energy Use is either a *credit* resulting in a *lower kBtu/sf-yr* of total proposed energy use, or a *penalty* resulting in a *higher kBtu/sf-y*r of total energy use.

Water Heating in the Performance Methods

Using the performance approach, *energy tradeoffs* can be made between water heating and space conditioning energy use. If the proposed water heating energy use is greater than the standard energy use, the water heating system and building comply as long as the total proposed design energy use, in kBtu/sf-yr, is the same or less than the total standard design energy budget using a computer method as explained in Chapter 5.

6.3 Instructions, Forms & Tables

The instructions presented in this part provide a step-by-step description for each worksheet and form. To see completed sample worksheets for different water heating systems, see Section 6.4. For an overview of which forms apply to which compliance scenarios, refer to Table 6-4.

The worksheet for Combined Hydronic Space and Water Heating, DHW-5, is contained in Section 6.5.

Heater type data is contained in the Commission's listing of certified water heaters. Data on water heaters, for use with a database program is also available from the Commission’s Web site at:

http://www.energy.ca.gov/appliances/appliances/

6.3.1 DHW-1, Water Heating Worksheet

Complete the DHW-1 form whenever there is a non-standard water heating system (see Sections 6.1 and 6.6). You may calculate up to three different heater types per sheet. If you have more than three different types, use additional copies of the worksheet.

The section of the worksheet entitled *Energy Use Calculation* refers to tables included at the end of this part.

Title Block

- Enter **Project Title** and **Date**.
- Enter the **Number of Different Water Heater Types** (this value may not necessarily be the same as the *total* number of individual water heaters in the building.)
- Enter the **Total No. of Water Heaters**.
- Enter the total **Conditioned Floor Area (CFA)** of the dwelling unit, in square feet. When multi-family water heaters are *shared* by more than one dwelling unit, compliance must be based on the average of the square feet of the dwelling units served by each (different) shared water heater. Enter this average dwelling unit CFA here.

Heater Type Data

For each column, enter the heater number (e.g., "Heater # 1 Data".) To identify which water heater on the plans matches these calculations.

A. Indicate the **Water Heater Type**. For a full listing of heater type descriptions and installation criteria, see Section 6.6. If the water heater is part of a hydronic system, see Section 6.5.

Note: Oil-fired water heaters are considered gas water heaters for the purpose of the water heating calculations.

B. List the Manufacturer.

C. List the Model No.

The next set of values (lines D, E, F and G) must be taken from the Commission's listing of Certified Water Heaters.

D. Enter the Energy Factor. If Indirect Gas or Large Gas Storage water heater, leave blank.

E. Enter the actual capacity of the heater in Gallons.

F. For Instantaneous Gas heater type, enter Pilot Btu/hr.

G. For Instantaneous Gas heater type only, enter Thermal (Recovery) Efficiency (also used on form DHW-3).

H. Renewable energy sources such as solar or a wood stove are considered Auxiliary Input to the system. Indicate with a checkmark if either applies. For a full description of auxiliary inputs, see Section 6.6.

I. Indicate the Distribution System. For a full listing of distribution descriptions and installation criteria, see Section 6.6. If the distribution system is part of a hydronic system, see Section 6.5.

Energy Use Calculation

All values entered in lines 1a, 1b, 1d, 1e, 2a, 2b, 2c, 2d and 3 are in million Btu/year per dwelling unit (MBtu/yr-unit).

1a. Enter the **Standard Recovery Load** from Table 6-5 based on the total conditioned floor area of the dwelling unit.

1b. For a "Standard" distribution system, enter zero (0).

For other distribution system types, select **Distribution Credit** (+) or **Penalty** (-) from Table 6-6A or Table 6-7B based on standard recovery load (line 1a).

Pipe insulation credit can only be taken with non-recirculating systems and demand recirculating systems.

1c. If there is a solar Auxiliary Input (line H), then use the conditioned floor area and a solar energy factor to select the **Solar Fraction** from Table 6-9. Otherwise, enter zero (0).

All solar water heating devices must be Solar Rating and Certification Corporation (SRCC) rated. A pre-approved solar water heating system includes the collectors and water heater. The SRCC may be contacted at:

Solar Rating and Certification Corporation
C/o FSEC, 1679 Clearlake Road
Cocoa, FL 32922-5703
(407) 638-1537
(407) 638-1010 (FAX)

1d. Multiply the Standard Recovery Load (Line 1a) with the Solar Fraction (Line 1c) to calculate the **Solar Energy Credit**.

1e. Subtract credits to calculate the **Adjusted Recovery Load** (subtract lines 1b and 1d from line 1a). Note that when line 1b is negative, line 1d increases.

2a. Based upon the Water Heater Type (line A) and the **Adjusted Recovery Load** (line 1e), find the **Basic Energy Use** as follows:

Storage Gas	Table 6-8A
Storage Electric	Table 6-8B
Storage Heat Pump	Table 6-8C
Instantaneous Gas	Table 6-8D
Instantaneous Electric	Table 6-8D
Indirect Gas	DHW-3
Large Storage Gas	DHW-3

The tables use values listed on this worksheet such as Energy Factor (line D), Adjusted Recovery Load (line 1e), Pilot Btu/hr and Recovery Efficiency.

Note: No interpolation is allowed in Table 6-8. Go into the rows and columns in those tables using the table values closest to the actual values.

2b. If there is a wood stove Auxiliary Input (line H), determine the **Wood Stove Boiler Credit Factor** from Table 6-10. Otherwise, enter zero (0).

Wood Stove Boiler credit factors in Table 6-10 vary by climate zone and may be used to compute the wood stove boiler credit with or without a recirculating pump. DHW-1 must be completed through line 2a before WSB credit is computed.

Note: As tabulated in Table 6-10, the credit for Wood Stove Boilers with recirculating pumps is 90% of the credit without pumps based on a base case 85 watt pump applied to a 1700 ft^2 house and adjusted for electric source energy.

2c. Multiply the Basic Energy Use (Line 2a) with the Wood Stove Boiler Credit Factor (Line 2b) to calculate the **Wood Stove Boiler Credit**.

2d. Subtract the Wood Stove Boiler credit to calculate the **Proposed Energy Use** (subtract line 2c from line 2a).

Standard Energy Use

3. Find the **Standard Energy Use** from Table 6-5 using the total conditioned floor area of the dwelling unit. Enter the value on line 3.
4. In the prescriptive compliance approach (Section 3.7), *the proposed water heating system complies if line 2*d *is less than or equal to line 3*.

6.3.2 DHW-2A, Water Heating for Single Family with Multiple Heaters

If you are completing the DHW-1 form for a single family unit with more than one water heater, you must also complete the DHW-2A form.

Title Block

Enter **Project Title** and **Date**.

Single Family Project Data

1. Enter the **Number of different water heater types** (this may not necessarily be the same as the *total* number of water heaters in the building.)
2. Enter the **Total conditioned floor area** of the dwelling unit.

3a, 3b & 3c.

Enter the **Number of Heaters** for each **Heater Number**, **Manufacturer** and **Model Number** listed on DHW-1.

4. The **Total Number of Water Heaters** is the sum of lines 3a, 3b and 3c.
5. Enter the **Standard Recovery Load** from Table 6-5 based on line 2, total conditioned floor area.

6. Calculate and enter the **Recovery Load per heater**, which is line 5 divided by line 4. Enter this value on DHW-1, line 1a, for each heater type. Complete DHW-1 calculations through line 2d for each heater type.
7. Calculate and enter the **Proposed Energy Use** for **Heater Type #1**, which is DHW-1 Heater #1 line 2d times line 3a.
8. Calculate and enter the **Proposed Energy Use** for **Heater Type #2**, which is DHW-1 Heater #2 line 2d times line 3b.
9. Calculate and enter the **Proposed Energy Use** for **Heater Type #3**, which is DHW-1 Heater #3 line 2d times line 3c.
10. Calculate and enter the **Total Proposed Energy Use**, which is the sum of lines 7, 8 and 9.
11. Enter the **Standard Energy Use** from Table 6-5 using line 2, total conditioned floor area.

Compliance

12. In the prescriptive compliance approach (see Chapter 3), the proposed water heating system complies if line 10 is equal to or less than line 11.

6.3.3 DHW-2B, Water Heating for Multi-Family

Complete the DHW-2B form for any multi-family project. The DHW-1 worksheet must also be completed whenever the DHW-2B form is submitted.

Title Block

Enter **Project Title** and **Date**.

Multi-Family Project Data

1. Enter the Number of dwelling units.
2. Enter the Total conditioned floor area of the building.
3. Calculate and enter the Average floor area per dwelling unit, which is line 2 divided by line 1.
4. Enter the **Standard Recovery Load** from Table 6-5 based on line 3, average conditioned floor area per dwelling unit.
5. Indicate which analytical method is used to calculate Proposed Energy Use: Average Dwelling Unit or Individual Dwelling Unit. For "Individual Dwelling Unit" analysis, complete only lines 1 through 5, and attach a DHW-1 form with a Heater # for each individual unit.
6. Indicate which System configuration is being installed in the building: Individual Heaters (one per dwelling unit) or Shared Heaters (multiple dwelling units per heater).

If Individual Heaters, follow instructions for lines 10a through 13a.

If Shared Heater(s), complete lines 10b-14b, and follow instructions on line 14b.

7a, 7b, & 7c.

Enter the **Number of Heaters** for each **Heater Number**, **Manufacturer** and **Model Number** listed. For Individual Heaters, also enter the volume in **Gallons** for **Each** heater, and for the **Total** number of heaters of that type; enter the **Energy Factor** for **Each** heater, and the **Total** value (which is the number of heaters times the EF). Enter the Thermal or Recovery (depending on the type of system) Efficiency for each heater and the Total value (which is the number of each type of heater times the model Thermal or Recovery Efficiency).

8a. Enter the **Total** number of heaters, which is the sum of lines 7a, 7b and 7c.

The following items (lines 8b, 8c, 8d, 9a and 9b) are calculated only for Individual Heaters.

8b. Enter the **Total** gallons of all heaters.

8c. Enter the **Total** of the Energy Factors.

8d. Enter the Total of the Thermal or Recovery Efficiencies.

9a. Calculate and enter the **Average** gallons per heater, which is line 8b divided by line 8a.

9b. Calculate and enter the **Average** Energy Factor per heater, which is line 8c divided by line 8a.

9c. Calculate and enter the Average Thermal or Recovery Efficiency per heater, which is line 8d divided by line 8a.

Individual Heaters

10a. Transfer the value from line 9a to DHW-1 line E (gallons).

11a. Transfer the value from line 9b to DHW-1 line D (Energy Factor).

12a. Transfer the value from line 9c to DHW-1 line G (Thermal or Recovery Efficiency)

13. Check compliance on DHW-1 for average dwelling unit and average water heater.

Shared Heater(s)

10b. Calculate and enter the **Average Unit Recovery Load**, which is DHW-1 line 1e.

11b. Calculate and enter the **Total Adjusted Recovery Load**, which is line 1 times line 10b.

12b. Enter the **Basic Energy Use** from Table 6-8, or from DHW-3 line 9 based on line 11b.

13b. Calculate and enter the **Average Unit Basic Energy Use**, which is transferred from DHW-1 line 2a.

14b. Verify compliance on DHW-1 for average dwelling unit.

15. In the prescriptive compliance approach (see Chapter 3), *the proposed water heating system complies if DHW-1 line 2*d *is less than or equal to DHW-1 line 3*.

6.3.4 DHW-3, Large Storage Gas or Indirect Gas Worksheet

Complete the DHW-3 for any project that includes a large storage gas heater or an indirect gas heater (as explained in Section 6.6). *The DHW-1 worksheet must also be completed whenever the DHW-3 form is submitted.*

Title Block

Enter **Project Title** and **Date**.

Indirect Gas Water Heaters

1. Enter the Storage tank Manufacturer and Model Number.
2. Enter the Boiler or Instantaneous Water Heater Manufacturer and Model Number.
3. Enter the Storage tank insulation R-value: The R-value integral with (internal to) the Tank; any External insulation R-value; and the Total of the two.
4. Enter the Storage tank volume in gallons.
5. Find the Boiler AFUE or Instantaneous Water Heater Recovery Efficiency in the appropriate appliance directory or database and enter on Line 5 in decimal fraction form (e.g., 0.78).
6. Enter the Adjusted Recovery Load on line 6 from DHW-1 Line 1e.

7. Using tank volume (Line 4) and Total R-Value (Line 3), determine Jacket Loss in MBtu/yr from Table 6-8E and enter on line 7.
8. Enter Pilot energy (Btu/hr) from appliance directory or database on line 8. Enter zero (0) for no pilot, or 800 if pilot exists but energy use is not listed in the appliance database.
9. Using the equation listed, calculate Basic Energy Use and enter the value on line 9. Also enter the value on DHW-1 Line 2a or DHW-2B Line 12b.

Large Storage Gas Water Heaters (>75,000 Btuh Input)

1. Enter the Water Heater Manufacturer.
2. Enter the Water Heater Model No.
3. Enter the actual Storage tank volume in gallons from the Appliance database.
4. Enter the Water Heater Thermal or Recovery Efficiency from the appliance database and enter on Line 4 in decimal fraction form (e.g. 0.78).
5. Enter the Adjusted Recovery Load, from DHW-1 Line 1e or from DHW-2B Line 11b, on Line 5.
6. Enter Standby loss % from the appliance database on line 6. (For example, enter "3.2" for 3.2%.)
7. Using the equation listed, calculate Basic Energy Use and enter the value on line 7. Also, enter the value on DHW-1 Line 2a or on DHW-2b Line 12b.

6.3.5 DHW-5, Combined Hydronic Space and Water Heating

Complete the DHW-5 for any project that includes a combined hydronic space and water heating system (as explained in Sections 6.5 and 8.8) to calculate the AFUE. The DHW-5 is also used to calculate the adjusted AFUE (accounting for pipe losses) when a space heating boiler is also used for water heating.

The DHW-1 worksheet must also be completed whenever the DHW-5 form is submitted.

If water heating is provided by a dedicated (separate) hydronic space heating system, complete the DHW-1 form only.

Storage Gas

1. Enter the Recovery Efficiency, or Thermal Efficiency, or Annual Fuel Utilization Efficiency (AFUE) (decimal) of the water heater or boiler.
2. Enter the calculated Average Hourly Pipe Loss, from the Pipe Loss Worksheet on the bottom of the DHW-5 form.
3. Enter the Rated Input of the water heater.
4. Determine the Effective AFUE of the system, by first dividing Line 2 by Line 3, then subtracting that value from Line 1. This value is used for prescriptive compliance.

Storage Electric

1. Enter the calculated **Average Hourly Pipe Loss**, from the Pipe Loss Worksheet on the bottom of the DHW-5 form.
2. Enter the **Rated Input** of the water heater.
3. Enter the **Pump Watts** of the water heater and all other pumps associated with the system.
4. Calculate **Term A** from Lines 1 and 2. Multiply Line 2 by 3.413, then divide Line 1 by this value. Subtract the result from 1.
5. Calculate **Term B** from Lines 2 and 3. Multiply Line 2 by 1000, then divide Line 3 by this value, and add 1.

6. Calculate the **Effective HSPF (no fan)** by first dividing Line 4 by Line 5, then multiplying the result by 3.413. This value is used in the packages.
7. Calculate the **Effective HSPF (with fan)** by first dividing 1 by Line 6, then adding 0.005. Next divide the result into 1.017. This value is used in the packages.

Heat Pump

1. Enter the **Energy Factor** (decimal) of the water heater.
2. Enter the **Average Hourly Pipe Loss** from the Pipe Loss Worksheet on the bottom of the DHW-5 form.
3. Enter the **Rated Input** of the water heater.
4. Determine the **Recovery Efficiency** of the water heater. Divide 1 by Line 1, then subtract 0.1175. Divide the result into 1.
5. Enter the **Climate Zone Adjustment** value from the table on the form.
6. Calculate the **Effective HSPF (no fan)** by first multiplying 3.413 by Line 3, then dividing this value into Line 2. Next subtract this value from the value resulting from dividing Line 4 by Line 5. Multiply this result by 3.413. This value is used in the packages.
7. Calculate the **Effective HSPF (with fan)** by first dividing 1 by Line 6, then adding 0.005. Next divide the result into 1.017. This value is used in the packages.

Pipe Loss Worksheet

1. Include **Description(s)** of any piping with more than 10 feet of pipe in unconditioned space between supply and distribution systems.
2. Enter **Pipe Loss Rate** for type(s) of pipe from table on the form.
3. Enter the **Pipe Length** of each pipe outside conditioned space.
4. Calculate **Total Pipe Loss** by multiplying pipe loss rate by pipe length.
5. Sum all pipe losses from step 4.
6. Divide the value from step 5 by 8760 to determine the **Average Hourly Pipe Loss (kBtu/hr)**.

If the **Pipe Losses** section is not applicable (less than 10 feet of pipe in unconditioned space), enter zero for the Average Hourly Pipe Loss.

Table 6-5 – Standard Recovery Load and Standard Energy Use

Floor Area	Standard Recovery Load	Standard Energy Use	Floor Area	Standard Recovery Load	Standard Energy Use
< 111	6.4	16.9	626 - 675	8.4	19.5
111 – 130	6.5	17.0	676 - 726	8.6	19.8
131 – 150	6.5	17.0	726 - 775	8.8	20.0
151 – 170	6.6	17.1	776 - 825	9.0	20.3
171 – 190	6.7	17.2	826 - 875	9.2	20.5
191 – 210	6.8	17.3	876 - 925	9.4	20.7
211 – 230	6.8	17.4	926 - 975	9.5	21.0
231 – 250	6.9	17.5	976 - 1050	9.8	21.3
251 – 270	7.0	17.6	1051 - 1150	10.1	21.7
271 – 290	7.1	17.7	1151 - 1250	10.5	22.2
291 – 310	7.1	17.8	1251 - 1350	10.9	22.7
311 – 330	7.2	17.9	1351 - 1450	11.3	23.2
331 – 350	7.3	18.0	1451 - 1550	11.6	23.6
351 – 370	7.3	18.1	1551 - 1650	12.0	24.1
371 – 390	7.4	18.2	1651 - 1750	12.4	24.6
391 – 410	7.5	18.3	1751 - 1850	12.8	25.1
411 – 430	7.6	18.4	1851 - 1950	13.2	25.6
431 – 450	7.6	18.5	1951 - 2050	13.6	26.1
451 – 470	7.7	18.6	2051 - 2150	14.0	26.6
471 – 490	7.8	18.7	2151 - 2250	14.4	27.0
491 – 525	7.9	18.8	2251 - 2350	14.8	27.5
526 – 575	8.0	19.0	2351 - 2500	15.3	28.1
576 – 625	8.2	19.3	> 2500	15.6	28.5

Table 6-6 – Distribution System Credit/Penalty[1] for Single Family Dwellings (per worksheet)

Standard Recovery Load	Standard	Point of Use	Pipe Insulation	Hot Water Recovery	Parallel Piping	Recirculation Systems: Time/Temp	Demand	Time	Temp	No Control
< 6.3	0.0	1.1	0.5	1.1	0.9	0.3	0.1	-1.8	-0.3	-3.3
6.3 – 6.99	0.0	1.2	0.5	1.2	0.9	0.3	0.1	-1.8	-0.3	-3.4
7.0 – 7.49	0.0	1.3	0.6	1.3	1.0	0.3	0.1	-2.0	-0.4	-3.7
7.5 – 7.99	0.0	1.4	0.6	1.4	1.1	0.3	0.2	-2.2	-0.4	-4.0
8.0 – 8.49	0.0	1.5	0.7	1.5	1.1	0.3	0.2	-2.3	-0.4	-4.3
8.5 – 8.99	0.0	1.6	0.7	1.6	1.2	0.3	0.2	-2.4	-0.4	-4.5
9.0 – 9.49	0.0	1.7	0.7	1.7	1.3	0.4	0.2	-2.6	-0.5	-4.8
9.5 – 9.99	0.0	1.7	0.8	1.7	1.4	0.4	0.2	-2.7	-0.5	-5.0
10.0 - 10.99	0.0	1.8	0.8	1.8	1.4	0.4	0.2	-2.9	-0.5	-5.3
11.0 - 11.99	0.0	2.0	0.9	2.0	1.6	0.4	0.2	-3.1	-0.6	-5.8
12.0 - 12.99	0.0	2.2	1.0	2.2	1.7	0.5	0.2	-3.4	-0.6	-6.3
13.0 - 13.99	0.0	2.4	1.1	2.4	1.8	0.5	0.3	-3.7	-0.7	-6.9
14.0 - 15.99	0.0	2.6	1.1	2.6	2.0	0.6	0.3	-4.0	-0.7	-7.4
16.0 - 17.99	0.0	2.9	1.3	2.9	2.3	0.6	0.3	-4.5	-0.8	-8.4
18.0 - 19.99	0.0	3.3	1.5	3.3	2.5	0.7	0.4	-5.1	-0.9	-9.5
20.0 - 21.99	0.0	3.6	1.6	3.6	2.8	0.8	0.4	-5.7	-1.0	-10.5
22.0 - 23.99	0.0	4.0	1.8	4.0	3.1	0.9	0.4	-6.2	-1.1	-11.5
24.0 - 25.99	0.0	4.4	1.9	4.4	3.4	1.0	0.5	-6.8	-1.2	-12.6
26.0+	0.0	4.8	2.1	4.8	3.7	1.1	0.5	-7.4	-1.3	-13.7

Table 6-7 – Distribution System Credit/Penalty[1] for Multi Family Dwellings (per worksheet)

						Recirculation Systems				
Standard Recovery Load	***Standard***	***Point of Use***	***Pipe Insulation***	***Hot Water Recovery***	***Parallel Piping***	***Time/Temp***	***Demand***	***Time***	***Temp***	***No Control***
< 6.3	0.0	0.0	0.5	0.0	0.9	-3.3	-3.3	-3.3	-0.3	-3.3
6.3 - 6.99	0.0	0.0	0.5	0.0	0.9	-3.4	-3.4	-3.4	-0.3	-3.4
7.0 - 7.49	0.0	0.0	0.6	0.0	1.0	-3.7	-3.7	-3.7	-0.4	-3.7
7.5 - 7.99	0.0	0.0	0.6	0.0	1.1	-4.0	-4.0	-4.0	-0.4	-4.0
8.0 - 8.49	0.0	0.0	0.7	0.0	1.1	-4.3	-4.3	-4.3	-0.4	-4.3
8.5 - 8.99	0.0	0.0	0.7	0.0	1.2	-4.5	-4.5	-4.5	-0.4	-4.5
9.0 - 9.49	0.0	0.0	0.7	0.0	1.3	-4.8	-4.8	-4.8	-0.5	-4.8
9.5 - 9.99	0.0	0.0	0.8	0.0	1.4	-5.0	-5.0	-5.0	-0.5	-5.0
10.0 - 10.99	0.0	0.0	0.8	0.0	1.4	-5.3	-5.3	-5.3	-0.5	-5.3
11.0 - 11.99	0.0	0.0	0.9	0.0	1.6	-5.8	-5.8	-5.8	-0.6	-5.8
12.0 - 12.99	0.0	0.0	1.0	0.0	1.7	-6.3	-6.3	-6.3	-0.6	-6.3
13.0 - 13.99	0.0	0.0	1.1	0.0	1.8	-6.9	-6.9	-6.9	-0.7	-6.9
14.0 - 15.99	0.0	0.0	1.1	0.0	2.0	-7.4	-7.4	-7.4	-0.7	-7.4
16.0 - 17.99	0.0	0.0	1.3	0.0	2.3	-8.4	-8.4	-8.4	-0.8	-8.4
18.0 - 19.99	0.0	0.0	1.5	0.0	2.5	-9.5	-9.5	-9.5	-0.9	-9.5
20.0 - 21.99	0.0	0.0	1.6	0.0	2.8	-10.5	-10.5	-10.5	-1.0	-10.5
22.0 - 23.99	0.0	0.0	1.8	0.0	3.1	-11.5	-11.5	-11.5	-1.1	-11.5
24.0 - 25.99	0.0	0.0	1.9	0.0	3.4	-12.6	-12.6	-12.6	-1.2	-12.6
26.0+	0.0	0.0	2.1	0.0	3.7	-13.7	-13.7	-13.7	-1.3	-13.7

1. Hot water recovery and pipe insulation credits may only be applied to non-recirculating systems and demand recirculating systems. All other recirculating systems must have pipe insulation as explained in Section 6.6.

Table 6-8A – Basic Energy Use (BEU) - Storage Gas Heater [no interpolation]*

Adjusted Recovery Load	Energy Factor																						
	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.74	0.78	0.82
3.0	19.9	18.5	17.3	16.2	15.3	14.4	13.7	13.0	12.4	11.8	11.3	10.8	10.4	10.0	9.3	8.7	8.1	7.7	7.2	6.8	6.2	5.7	5.2
3.2	19.6	18.3	17.2	16.2	15.3	14.5	13.8	13.1	12.6	12.0	11.5	11.1	10.6	10.3	9.6	8.9	8.4	7.9	7.5	7.1	6.5	5.9	5.5
3.4	19.4	18.2	17.2	16.2	15.4	14.6	14.0	13.3	12.8	12.2	11.8	11.3	10.9	10.5	9.8	9.2	8.7	8.2	7.8	7.4	6.7	6.2	5.7
3.6	19.3	18.2	17.2	16.3	15.5	14.8	14.2	13.6	13.0	12.5	12.0	11.6	11.2	10.8	10.1	9.5	9.0	8.5	8.1	7.7	7.0	6.4	5.9
3.8	19.3	18.2	17.3	16.5	15.7	15.0	14.4	13.8	13.2	12.7	12.3	11.8	11.4	11.1	10.4	9.8	9.2	8.8	8.3	7.9	7.3	6.7	6.2
4.0	19.3	18.3	17.4	16.6	15.9	15.2	14.6	14.0	13.5	13.0	12.5	12.1	11.7	11.3	10.7	10.1	9.5	9.0	8.6	8.2	7.5	6.9	6.4
4.2	19.4	18.4	17.6	16.8	16.1	15.4	14.8	14.2	13.7	13.2	12.8	12.4	12.0	11.6	10.9	10.3	9.8	9.3	8.9	8.5	7.8	7.2	6.7
4.4	19.5	18.6	17.7	17.0	16.3	15.6	15.0	14.5	14.0	13.5	13.1	12.6	12.3	11.9	11.2	10.6	10.1	9.6	9.1	8.7	8.0	7.4	6.9
4.6	19.6	18.7	17.9	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.2	11.5	10.9	10.3	9.8	9.4	9.0	8.3	7.7	7.1
4.8	19.8	18.9	18.1	17.4	16.7	16.1	15.5	15.0	14.5	14.0	13.6	13.2	12.8	12.4	11.8	11.2	10.6	10.1	9.7	9.3	8.5	7.9	7.4
5.0	19.9	19.1	18.3	17.6	17.0	16.4	15.8	15.3	14.8	14.3	13.9	13.5	13.1	12.7	12.0	11.4	10.9	10.4	9.9	9.5	8.8	8.1	7.6
5.2	20.1	19.3	18.5	17.8	17.2	16.6	16.0	15.5	15.0	14.6	14.1	13.7	13.3	13.0	12.3	11.7	11.1	10.6	10.2	9.8	9.0	8.4	7.8
5.4	20.3	19.5	18.8	18.1	17.4	16.9	16.3	15.8	15.3	14.8	14.4	14.0	13.6	13.2	12.6	12.0	11.4	10.9	10.4	10.0	9.3	8.6	8.1
5.6	20.5	19.7	19.0	18.3	17.7	17.1	16.6	16.0	15.6	15.1	14.7	14.3	13.9	13.5	12.8	12.2	11.7	11.2	10.7	10.3	9.5	8.9	8.3
5.8	20.7	19.9	19.2	18.6	17.9	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.8	13.1	12.5	11.9	11.4	11.0	10.5	9.8	9.1	8.5
6.0	20.9	20.2	19.5	18.8	18.2	17.6	17.1	16.6	16.1	15.6	15.2	14.8	14.4	14.0	13.4	12.8	12.2	11.7	11.2	10.8	10.0	9.3	8.7
6.2	21.2	20.4	19.7	19.1	18.4	17.9	17.3	16.8	16.3	15.9	15.5	15.1	14.7	14.3	13.6	13.0	12.5	11.9	11.5	11.0	10.2	9.6	9.0
6.4	21.4	20.6	20.0	19.3	18.7	18.1	17.6	17.1	16.6	16.2	15.7	15.3	14.9	14.6	13.9	13.3	12.7	12.2	11.7	11.3	10.5	9.8	9.2
6.6	21.6	20.9	20.2	19.6	19.0	18.4	17.9	17.4	16.9	16.4	16.0	15.6	15.2	14.8	14.2	13.5	13.0	12.4	12.0	11.5	10.7	10.0	9.4
6.8	21.9	21.1	20.5	19.8	19.2	18.7	18.1	17.6	17.1	16.7	16.3	15.9	15.5	15.1	14.4	13.8	13.2	12.7	12.2	11.8	10.9	10.2	9.6
7.0	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.9	17.4	17.0	16.5	16.1	15.7	15.4	14.7	14.1	13.5	12.9	12.5	12.0	11.2	10.5	9.8
7.2	22.3	21.6	21.0	20.3	19.7	19.2	18.6	18.1	17.7	17.2	16.8	16.4	16.0	15.6	14.9	14.3	13.7	13.2	12.7	12.2	11.4	10.7	10.1
7.4	22.6	21.9	21.2	20.6	20.0	19.4	18.9	18.4	17.9	17.5	17.1	16.7	16.3	15.9	15.2	14.6	14.0	13.4	12.9	12.5	11.6	10.9	10.3
7.6	22.8	22.1	21.5	20.8	20.3	19.7	19.2	18.7	18.2	17.8	17.3	16.9	16.5	16.2	15.5	14.8	14.2	13.7	13.2	12.7	11.9	11.1	10.5
7.8	23.1	22.4	21.7	21.1	20.5	20.0	19.4	18.9	18.5	18.0	17.6	17.2	16.8	16.4	15.7	15.1	14.5	13.9	13.4	13.0	12.1	11.4	10.7
8.0	23.3	22.6	22.0	21.4	20.8	20.2	19.7	19.2	18.7	18.3	17.8	17.4	17.0	16.7	16.0	15.3	14.7	14.2	13.7	13.2	12.3	11.6	10.9
8.2	23.6	22.9	22.2	21.6	21.0	20.5	20.0	19.5	19.0	18.5	18.1	17.7	17.3	16.9	16.2	15.6	15.0	14.4	13.9	13.4	12.6	11.8	11.1
8.4	23.8	23.1	22.5	21.9	21.3	20.7	20.2	19.7	19.3	18.8	18.4	18.0	17.6	17.2	16.5	15.8	15.2	14.7	14.2	13.7	12.8	12.0	11.3
8.6	24.1	23.4	22.8	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.4	16.7	16.1	15.5	14.9	14.4	13.9	13.0	12.2	11.6
8.8	24.3	23.7	23.0	22.4	21.8	21.3	20.7	20.2	19.8	19.3	18.9	18.5	18.1	17.7	17.0	16.3	15.7	15.2	14.6	14.1	13.2	12.5	11.8
9.0	24.6	23.9	23.3	22.7	22.1	21.5	21.0	20.5	20.0	19.6	19.1	18.7	18.3	18.0	17.2	16.6	16.0	15.4	14.9	14.4	13.5	12.7	12.0
9.2	24.8	24.2	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.8	19.4	19.0	18.6	18.2	17.5	16.8	16.2	15.6	15.1	14.6	13.7	12.9	12.2
9.4	25.1	24.4	23.8	23.2	22.6	22.0	21.5	21.0	20.5	20.1	19.7	19.2	18.8	18.5	17.7	17.1	16.4	15.9	15.3	14.8	13.9	13.1	12.4
9.6	25.4	24.7	24.0	23.4	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.0	17.3	16.7	16.1	15.6	15.1	14.1	13.3	12.6
9.8	25.6	24.9	24.3	23.7	23.1	22.6	22.0	21.5	21.1	20.6	20.2	19.7	19.3	19.0	18.2	17.6	16.9	16.3	15.8	15.3	14.4	13.5	12.8
10.0	25.9	25.2	24.6	23.9	23.4	22.8	22.3	21.8	21.3	20.9	20.4	20.0	19.6	19.2	18.5	17.8	17.2	16.6	16.0	15.5	14.6	13.8	13.0
10.5	26.5	25.8	25.2	24.6	24.0	23.5	22.9	22.4	22.0	21.5	21.0	20.6	20.2	19.8	19.1	18.4	17.8	17.2	16.6	16.1	15.1	14.3	13.5
11.0	27.1	26.5	25.8	25.2	24.7	24.1	23.6	23.1	22.6	22.1	21.7	21.2	20.8	20.4	19.7	19.0	18.4	17.7	17.2	16.6	15.7	14.8	14.0
11.5	27.8	27.1	26.5	25.9	25.3	24.7	24.2	23.7	23.2	22.7	22.3	21.9	21.5	21.1	20.3	19.6	18.9	18.3	17.7	17.2	16.2	15.3	14.5
12.0	28.4	27.7	27.1	26.5	25.9	25.4	24.8	24.3	23.8	23.4	22.9	22.5	22.1	21.7	20.9	20.2	19.5	18.9	18.3	17.8	16.8	15.9	15.1
12.5	29.0	28.4	27.7	27.1	26.6	26.0	25.5	25.0	24.5	24.0	23.5	23.1	22.7	22.3	21.5	20.8	20.1	19.5	18.9	18.3	17.3	16.4	15.6
13.0	29.7	29.0	28.4	27.8	27.2	26.6	26.1	25.6	25.1	24.6	24.1	23.7	23.3	22.9	22.1	21.3	20.7	20.0	19.4	18.9	17.8	16.9	16.0
13.5	30.3	29.6	29.0	28.4	27.8	27.2	26.7	26.2	25.7	25.2	24.7	24.3	23.9	23.5	22.7	21.9	21.2	20.6	20.0	19.4	18.3	17.4	16.5
14.0	30.9	30.3	29.6	29.0	28.4	27.9	27.3	26.8	26.3	25.8	25.3	24.9	24.5	24.0	23.2	22.5	21.8	21.1	20.5	19.9	18.9	17.9	17.0
14.5	31.6	30.9	30.3	29.6	29.0	28.5	27.9	27.4	26.9	26.4	25.9	25.5	25.1	24.6	23.8	23.1	22.4	21.7	21.1	20.5	19.4	18.4	17.5
15.0	32.2	31.5	30.9	30.3	29.7	29.1	28.5	28.0	27.5	27.0	26.5	26.1	25.6	25.2	24.4	23.6	22.9	22.2	21.6	21.0	19.9	18.9	18.0
15.5	32.8	32.1	31.5	30.9	30.3	29.7	29.1	28.6	28.1	27.6	27.1	26.7	26.2	25.8	25.0	24.2	23.5	22.8	22.2	21.5	20.4	19.4	18.5
16.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.2	28.7	28.2	27.7	27.3	26.8	26.4	25.5	24.8	24.0	23.3	22.7	22.1	20.9	19.9	19.0
16.5	34.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.3	28.8	28.3	27.8	27.4	26.9	26.1	25.3	24.6	23.9	23.2	22.6	21.4	20.4	19.5
17.0	34.7	34.0	33.3	32.7	32.1	31.5	30.9	30.4	29.9	29.4	28.9	28.4	28.0	27.5	26.7	25.9	25.1	24.4	23.8	23.1	22.0	20.9	19.9
17.5	35.3	34.6	33.9	33.3	32.7	32.1	31.5	31.0	30.5	30.0	29.5	29.0	28.5	28.1	27.2	26.4	25.7	25.0	24.3	23.6	22.5	21.4	20.4
18.0	35.9	35.2	34.5	33.9	33.3	32.7	32.1	31.6	31.1	30.5	30.0	29.6	29.1	28.6	27.8	27.0	26.2	25.5	24.8	24.2	23.0	21.9	20.9
18.5	36.5	35.8	35.1	34.5	33.9	33.3	32.7	32.2	31.6	31.1	30.6	30.1	29.7	29.2	28.3	27.5	26.8	26.0	25.3	24.7	23.5	22.4	21.4
19.0	37.1	36.4	35.7	35.1	34.5	33.9	33.3	32.8	32.2	31.7	31.2	30.7	30.2	29.8	28.9	28.1	27.3	26.5	25.8	25.2	24.0	22.8	21.8
19.5	37.7	37.0	36.3	35.7	35.1	34.5	33.9	33.3	32.8	32.3	31.8	31.3	30.8	30.3	29.4	28.6	27.8	27.1	26.4	25.7	24.5	23.3	22.3
20.0	38.3	37.6	36.9	36.3	35.7	35.1	34.5	33.9	33.4	32.8	32.3	31.8	31.3	30.9	30.0	29.1	28.4	27.6	26.9	26.2	24.9	23.8	22.8
21.0	39.5	38.8	38.1	37.4	36.8	36.2	35.6	35.1	34.5	34.0	33.4	32.9	32.5	32.0	31.1	30.2	29.4	28.6	27.9	27.2	25.9	24.8	23.7
22.0	40.7	40.0	39.3	38.6	38.0	37.4	36.8	36.2	35.6	35.1	34.6	34.1	33.6	33.1	32.2	31.3	30.5	29.7	28.9	28.2	26.9	25.7	24.6

* The Basic Energy Use obtained from this table is used on Form DHW-1, line 2a.

Table 6-8B – Basic Energy Use (BEU) - Storage Electric Heater [no interpolation]*

Adj Recovery Load	Energy Factor																						
	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
3.0	22.4	21.1	20.0	19.0	18.1	17.2	16.5	15.8	15.2	14.6	14.0	13.5	13.0	12.6	12.2	11.8	11.5	11.1	10.8	10.5	10.2	9.9	9.7
3.2	23.0	21.8	20.7	19.7	18.8	18.0	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.1	11.8	11.5	11.1	10.8	10.6	10.3
3.4	23.6	22.4	21.3	20.4	19.5	18.7	17.9	17.2	16.6	16.0	15.4	14.9	14.4	14.0	13.6	13.2	12.8	12.4	12.1	11.8	11.5	11.2	10.9
3.6	24.2	23.1	22.0	21.1	20.2	19.4	18.6	17.9	17.3	16.7	16.1	15.6	15.1	14.7	14.2	13.8	13.5	13.1	12.7	12.4	12.1	11.8	11.5
3.8	24.8	23.7	22.7	21.7	20.9	20.1	19.3	18.6	18.0	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.7	13.4	13.1	12.7	12.4	12.1
4.0	25.5	24.4	23.3	22.4	21.6	20.8	20.0	19.3	18.7	18.1	17.5	17.0	16.5	16.0	15.6	15.2	14.8	14.4	14.0	13.7	13.4	13.1	12.8
4.2	26.1	25.0	24.0	23.1	22.2	21.4	20.7	20.0	19.4	18.8	18.2	17.7	17.2	16.7	16.3	15.8	15.4	15.0	14.7	14.3	14.0	13.7	13.4
4.4	26.7	25.6	24.7	23.8	22.9	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.8	17.4	16.9	16.5	16.1	15.7	15.3	15.0	14.6	14.3	14.0
4.6	27.3	26.3	25.3	24.4	23.6	22.8	22.1	21.4	20.7	20.1	19.6	19.0	18.5	18.0	17.6	17.1	16.7	16.3	15.9	15.6	15.2	14.9	14.6
4.8	28.0	26.9	26.0	25.1	24.3	23.5	22.7	22.1	21.4	20.8	20.2	19.7	19.2	18.7	18.2	17.8	17.4	17.0	16.6	16.2	15.9	15.5	15.2
5.0	28.6	27.6	26.6	25.7	24.9	24.1	23.4	22.7	22.1	21.5	20.9	20.4	19.8	19.3	18.9	18.4	18.0	17.6	17.2	16.8	16.5	16.1	15.8
5.2	29.2	28.2	27.3	26.4	25.6	24.8	24.1	23.4	22.7	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.5	17.1	16.7	16.4
5.4	29.8	28.8	27.9	27.0	26.2	25.5	24.7	24.1	23.4	22.8	22.2	21.7	21.1	20.6	20.2	19.7	19.3	18.9	18.5	18.1	17.7	17.4	17.0
5.6	30.4	29.5	28.5	27.7	26.9	26.1	25.4	24.7	24.1	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.3	18.0	17.6
5.8	31.0	30.1	29.2	28.3	27.5	26.8	26.0	25.4	24.7	24.1	23.5	23.0	22.4	21.9	21.4	21.0	20.5	20.1	19.7	19.3	18.9	18.6	18.2
6.0	31.6	30.7	29.8	29.0	28.2	27.4	26.7	26.0	25.4	24.7	24.2	23.6	23.1	22.6	22.1	21.6	21.2	20.7	20.3	19.9	19.5	19.2	18.8
6.2	32.3	31.3	30.4	29.6	28.8	28.0	27.3	26.7	26.0	25.4	24.8	24.2	23.7	23.2	22.7	22.2	21.8	21.4	20.9	20.5	20.2	19.8	19.4
6.4	32.9	31.9	31.1	30.2	29.4	28.7	28.0	27.3	26.6	26.0	25.4	24.9	24.3	23.8	23.3	22.9	22.4	22.0	21.6	21.2	20.8	20.4	20.0
6.6	33.5	32.5	31.7	30.8	30.1	29.3	28.6	27.9	27.3	26.7	26.1	25.5	25.0	24.5	24.0	23.5	23.0	22.6	22.2	21.8	21.4	21.0	20.6
6.8	34.1	33.2	32.3	31.5	30.7	29.9	29.2	28.6	27.9	27.3	26.7	26.2	25.6	25.1	24.6	24.1	23.7	23.2	22.8	22.4	22.0	21.6	21.2
7.0	34.7	33.8	32.9	32.1	31.3	30.6	29.9	29.2	28.6	27.9	27.3	26.8	26.2	25.7	25.2	24.7	24.3	23.8	23.4	23.0	22.6	22.2	21.8
7.2	35.3	34.4	33.5	32.7	31.9	31.2	30.5	29.8	29.2	28.6	28.0	27.4	26.9	26.3	25.8	25.4	24.9	24.4	24.0	23.6	23.2	22.8	22.4
7.4	35.9	35.0	34.1	33.3	32.6	31.8	31.1	30.5	29.8	29.2	28.6	28.0	27.5	27.0	26.5	26.0	25.5	25.1	24.6	24.2	23.8	23.4	23.0
7.6	36.5	35.6	34.7	33.9	33.2	32.4	31.7	31.1	30.4	29.8	29.2	28.7	28.1	27.6	27.1	26.6	26.1	25.7	25.2	24.8	24.4	24.0	23.6
7.8	37.0	36.2	35.3	34.5	33.8	33.1	32.4	31.7	31.1	30.4	29.8	29.3	28.7	28.2	27.7	27.2	26.7	26.3	25.8	25.4	25.0	24.6	24.2
8.0	37.6	36.8	35.9	35.2	34.4	33.7	33.0	32.3	31.7	31.1	30.5	29.9	29.4	28.8	28.3	27.8	27.3	26.9	26.4	26.0	25.6	25.2	24.8
8.2	38.2	37.4	36.5	35.8	35.0	34.3	33.6	32.9	32.3	31.7	31.1	30.5	30.0	29.4	28.9	28.4	28.0	27.5	27.0	26.6	26.2	25.8	25.4
8.4	38.8	37.9	37.1	36.4	35.6	34.9	34.2	33.5	32.9	32.3	31.7	31.1	30.6	30.0	29.5	29.0	28.6	28.1	27.7	27.2	26.8	26.4	26.0
8.6	39.4	38.5	37.7	37.0	36.2	35.5	34.8	34.2	33.5	32.9	32.3	31.7	31.2	30.7	30.1	29.7	29.2	28.7	28.3	27.8	27.4	27.0	26.6
8.8	40.0	39.1	38.3	37.6	36.8	36.1	35.4	34.8	34.1	33.5	32.9	32.4	31.8	31.3	30.8	30.3	29.8	29.3	28.9	28.4	28.0	27.6	27.2
9.0	40.5	39.7	38.9	38.1	37.4	36.7	36.0	35.4	34.7	34.1	33.5	33.0	32.4	31.9	31.4	30.9	30.4	29.9	29.5	29.0	28.6	28.2	27.8
9.2	41.1	40.3	39.5	38.7	38.0	37.3	36.6	36.0	35.3	34.7	34.1	33.6	33.0	32.5	32.0	31.5	31.0	30.5	30.1	29.6	29.2	28.8	28.4
9.4	41.7	40.9	40.1	39.3	38.6	37.9	37.2	36.6	35.9	35.3	34.7	34.2	33.6	33.1	32.6	32.1	31.6	31.1	30.7	30.2	29.8	29.4	29.0
9.6	42.3	41.4	40.7	39.9	39.2	38.5	37.8	37.2	36.5	35.9	35.3	34.8	34.2	33.7	33.2	32.7	32.2	31.7	31.3	30.8	30.4	30.0	29.5
9.8	42.8	42.0	41.2	40.5	39.8	39.1	38.4	37.8	37.1	36.5	35.9	35.4	34.8	34.3	33.8	33.3	32.8	32.3	31.9	31.4	31.0	30.5	30.1
10.0	43.4	42.6	41.8	41.1	40.4	39.7	39.0	38.4	37.7	37.1	36.5	36.0	35.4	34.9	34.4	33.9	33.4	32.9	32.4	32.0	31.6	31.1	30.7
10.5	44.8	44.0	43.3	42.5	41.8	41.1	40.5	39.8	39.2	38.6	38.0	37.5	36.9	36.4	35.9	35.4	34.9	34.4	33.9	33.5	33.0	32.6	32.2
11.0	46.2	45.4	44.7	44.0	43.3	42.6	41.9	41.3	40.7	40.1	39.5	39.0	38.4	37.9	37.4	36.8	36.4	35.9	35.4	35.0	34.5	34.1	33.7
11.5	47.6	46.8	46.1	45.4	44.7	44.0	43.4	42.8	42.2	41.6	41.0	40.4	39.9	39.3	38.8	38.3	37.8	37.4	36.9	36.4	36.0	35.6	35.1
12.0	49.0	48.2	47.5	46.8	46.1	45.5	44.8	44.2	43.6	43.0	42.5	41.9	41.3	40.8	40.3	39.8	39.3	38.8	38.4	37.9	37.5	37.0	36.6
12.5	50.3	49.6	48.9	48.2	47.6	46.9	46.3	45.7	45.1	44.5	43.9	43.4	42.8	42.3	41.8	41.3	40.8	40.3	39.8	39.4	38.9	38.5	38.1
13.0	51.7	51.0	50.3	49.6	49.0	48.3	47.7	47.1	46.5	45.9	45.4	44.8	44.3	43.7	43.2	42.7	42.2	41.8	41.3	40.8	40.4	40.0	39.5
13.5	53.1	52.4	51.7	51.0	50.4	49.7	49.1	48.5	47.9	47.3	46.8	46.2	45.7	45.2	44.7	44.2	43.7	43.2	42.8	42.3	41.8	41.4	41.0
14.0	54.4	53.7	53.0	52.4	51.7	51.1	50.5	49.9	49.3	48.8	48.2	47.7	47.2	46.6	46.1	45.6	45.1	44.7	44.2	43.8	43.3	42.9	42.4
14.5	55.7	55.1	54.4	53.8	53.1	52.5	51.9	51.3	50.8	50.2	49.6	49.1	48.6	48.1	47.6	47.1	46.6	46.1	45.7	45.2	44.8	44.3	43.9
15.0	57.1	56.4	55.7	55.1	54.5	53.9	53.3	52.7	52.2	51.6	51.1	50.5	50.0	49.5	49.0	48.5	48.0	47.6	47.1	46.7	46.2	45.8	45.3
15.5	58.4	57.7	57.1	56.5	55.9	55.3	54.7	54.1	53.6	53.0	52.5	52.0	51.4	50.9	50.4	50.0	49.5	49.0	48.5	48.1	47.7	47.2	46.8
16.0	59.7	59.1	58.4	57.8	57.2	56.6	56.1	55.5	54.9	54.4	53.9	53.4	52.9	52.4	51.9	51.4	50.9	50.4	50.0	49.5	49.1	48.7	48.2
16.5	61.0	60.4	59.8	59.2	58.6	58.0	57.4	56.9	56.3	55.8	55.3	54.8	54.3	53.8	53.3	52.8	52.3	51.9	51.4	51.0	50.5	50.1	49.7
17.0	62.3	61.7	61.1	60.5	59.9	59.4	58.8	58.3	57.7	57.2	56.7	56.2	55.7	55.2	54.7	54.2	53.8	53.3	52.9	52.4	52.0	51.6	51.1
17.5	63.6	63.0	62.4	61.8	61.3	60.7	60.2	59.6	59.1	58.6	58.1	57.6	57.1	56.6	56.1	55.6	55.2	54.7	54.3	53.9	53.4	53.0	52.6
18.0	64.9	64.3	63.7	63.1	62.6	62.0	61.5	61.0	60.5	59.9	59.4	59.0	58.5	58.0	57.5	57.1	56.6	56.2	55.7	55.3	54.9	54.4	54.0
18.5	66.1	65.6	65.0	64.5	63.9	63.4	62.8	62.3	61.8	61.3	60.8	60.3	59.9	59.4	58.9	58.5	58.0	57.6	57.1	56.7	56.3	55.9	55.5
19.0	67.4	66.9	66.3	65.8	65.2	64.7	64.2	63.7	63.2	62.7	62.2	61.7	61.2	60.8	60.3	59.9	59.4	59.0	58.6	58.1	57.7	57.3	56.9
19.5	68.7	68.1	67.6	67.1	66.5	66.0	65.5	65.0	64.5	64.0	63.6	63.1	62.6	62.2	61.7	61.3	60.8	60.4	60.0	59.6	59.2	58.7	58.3
20.0	70.0	69.4	68.9	68.4	67.9	67.3	66.8	66.4	65.9	65.4	64.9	64.5	64.0	63.6	63.1	62.7	62.3	61.8	61.4	61.0	60.6	60.2	59.8
21.0	72.5	71.9	71.4	70.9	70.5	70.0	69.5	69.0	68.6	68.1	67.6	67.2	66.8	66.3	65.9	65.5	65.1	64.6	64.2	63.8	63.4	63.0	62.7
22.0	74.9	74.5	74.0	73.5	73.0	72.6	72.1	71.7	71.2	70.8	70.3	69.9	69.5	69.1	68.7	68.2	67.8	67.4	67.1	66.7	66.3	65.9	65.5

* The Basic Energy Use obtained from this table is used on Form DHW-1, line 2a.

Table 6-8C – Basic Energy Use (BEU) - Storage Heat Pump Heater [no interpolation]*

Adjusted Recovery Load	Energy Factor																				
	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
6.0	14.1	13.5	13.0	12.6	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	8.1	7.9	7.8
6.2	14.4	13.8	13.3	12.8	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.3	9.1	8.9	8.7	8.4	8.2	8.0	7.9
6.4	14.7	14.1	13.5	13.0	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.8	8.6	8.3	8.2	8.0
6.6	14.9	14.3	13.8	13.2	12.8	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5	8.3	8.1
6.8	15.2	14.6	14.0	13.5	13.0	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6	8.4	8.2
7.0	15.5	14.8	14.2	13.7	13.2	12.7	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5	8.3
7.2	15.8	15.1	14.5	13.9	13.4	12.9	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6	8.4
7.4	16.0	15.4	14.7	14.2	13.6	13.1	12.7	12.2	11.8	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5
7.6	16.3	15.6	15.0	14.4	13.8	13.3	12.9	12.4	12.0	11.6	11.3	10.9	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6
7.8	16.6	15.9	15.2	14.6	14.0	13.5	13.0	12.6	12.2	11.8	11.4	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.2	8.9	8.7
8.0	16.8	16.1	15.4	14.8	14.3	13.7	13.2	12.8	12.4	12.0	11.6	11.2	10.9	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8
8.2	17.1	16.4	15.7	15.0	14.5	13.9	13.4	13.0	12.5	12.1	11.7	11.4	11.0	10.7	10.4	10.1	9.9	9.6	9.4	9.2	8.9
8.4	17.4	16.6	15.9	15.3	14.7	14.1	13.6	13.1	12.7	12.3	11.9	11.5	11.2	10.9	10.6	10.3	10.0	9.7	9.5	9.3	9.0
8.6	17.7	16.9	16.1	15.5	14.9	14.3	13.8	13.3	12.9	12.4	12.0	11.7	11.3	11.0	10.7	10.4	10.1	9.9	9.6	9.4	9.1
8.8	17.9	17.1	16.4	15.7	15.1	14.5	14.0	13.5	13.0	12.6	12.2	11.8	11.5	11.1	10.8	10.5	10.2	10.0	9.7	9.5	9.3
9.0	18.2	17.4	16.6	15.9	15.3	14.7	14.2	13.7	13.2	12.8	12.4	12.0	11.6	11.3	11.0	10.7	10.4	10.1	9.8	9.6	9.4
9.2	18.4	17.6	16.8	16.1	15.5	14.9	14.4	13.9	13.4	12.9	12.5	12.1	11.8	11.4	11.1	10.8	10.5	10.2	10.0	9.7	9.5
9.4	18.7	17.9	17.1	16.4	15.7	15.1	14.5	14.0	13.5	13.1	12.7	12.3	11.9	11.5	11.3	10.9	10.6	10.3	10.1	9.8	9.6
9.6	19.0	18.1	17.3	16.6	15.9	15.3	14.7	14.2	13.7	13.3	12.8	12.4	12.0	11.7	11.4	11.0	10.7	10.5	10.2	9.9	9.7
9.8	19.2	18.3	17.5	16.8	16.1	15.5	14.9	14.4	13.9	13.4	13.0	12.6	12.2	11.8	11.5	11.2	10.9	10.6	10.3	10.0	9.8
10.0	19.5	18.6	17.8	17.0	16.3	15.7	15.1	14.6	14.0	13.6	13.1	12.7	12.3	12.0	11.7	11.3	11.0	10.7	10.4	10.1	9.9
10.5	20.1	19.2	18.3	17.6	16.8	16.2	15.6	15.0	14.5	14.0	13.5	13.1	12.7	12.3	11.9	11.6	11.3	11.0	10.7	10.4	10.2
11.0	20.8	19.8	18.9	18.1	17.3	16.7	16.0	15.4	14.9	14.4	13.9	13.4	13.0	12.6	12.3	11.9	11.6	11.3	11.0	10.7	10.4
11.5	21.4	20.4	19.5	18.6	17.8	17.1	16.5	15.9	15.3	14.8	14.3	13.8	13.4	13.0	12.6	12.2	11.9	11.6	11.3	11.0	10.7
12.0	22.1	21.0	20.0	19.1	18.3	17.6	16.9	16.3	15.7	15.1	14.6	14.2	13.7	13.3	12.9	12.5	12.2	11.9	11.5	11.2	11.0
12.5	22.7	21.6	20.6	19.7	18.8	18.1	17.4	16.7	16.1	15.5	15.0	14.5	14.1	13.6	13.2	12.8	12.5	12.1	11.8	11.5	11.2
13.0	23.3	22.2	21.1	20.2	19.3	18.5	17.8	17.1	16.5	15.9	15.4	14.9	14.4	14.0	13.5	13.1	12.8	12.4	12.1	11.8	11.5
13.5	23.9	22.7	21.7	20.7	19.8	19.0	18.2	17.6	16.9	16.3	15.8	15.2	14.7	14.3	13.9	13.5	13.1	12.7	12.4	12.0	11.7
14.0	24.5	23.3	22.2	21.2	20.3	19.5	18.7	18.0	17.3	16.7	16.1	15.6	15.1	14.6	14.2	13.8	13.4	13.0	12.6	12.3	12.0
14.5	25.2	23.9	22.8	21.7	20.8	19.9	19.1	18.4	17.7	17.1	16.5	15.9	15.4	14.9	14.5	14.1	13.7	13.3	12.9	12.6	12.3
15.0	25.8	24.5	23.3	22.2	21.3	20.4	19.6	18.8	18.1	17.4	16.8	16.3	15.8	15.3	14.8	14.4	13.9	13.6	13.2	12.8	12.5
15.5	26.4	25.0	23.8	22.7	21.7	20.8	20.0	19.2	18.5	17.8	17.2	16.6	16.1	15.6	15.1	14.7	14.2	13.8	13.5	13.1	12.8
16.0	27.0	25.6	24.4	23.2	22.2	21.3	20.4	19.6	18.9	18.2	17.6	17.0	16.4	15.9	15.4	15.0	14.5	14.1	13.7	13.4	13.0
16.5	27.6	26.2	24.9	23.7	22.7	21.7	20.8	20.0	19.3	18.6	17.9	17.3	16.7	16.2	15.7	15.2	14.8	14.4	14.0	13.6	13.3
17.0	28.2	26.7	25.4	24.2	23.2	22.2	21.3	20.4	19.7	18.9	18.3	17.7	17.1	16.5	16.0	15.5	15.1	14.7	14.3	13.9	13.5
17.5	28.8	27.3	25.9	24.7	23.6	22.6	21.7	20.8	20.0	19.3	18.6	18.0	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.8
18.0	29.4	27.8	26.5	25.2	24.1	23.1	22.1	21.2	20.4	19.7	19.0	18.3	17.7	17.2	16.6	16.1	15.7	15.2	14.8	14.4	14.0
18.5	29.9	28.4	27.0	25.7	24.5	23.5	22.5	21.6	20.8	20.0	19.3	18.7	18.0	17.5	16.9	16.4	15.9	15.5	15.1	14.7	14.3
19.0	30.5	28.9	27.5	26.2	25.0	23.9	23.3	22.0	21.2	20.4	19.7	19.0	18.4	17.8	17.2	16.7	16.2	15.8	15.3	14.9	14.5
19.5	31.1	29.5	28.0	26.7	25.5	24.4	23.3	22.4	21.6	20.8	20.0	19.3	18.7	18.1	17.5	17.0	16.5	16.0	15.6	15.2	14.8
20.0	31.7	30.0	28.5	27.2	25.9	24.8	23.8	22.8	21.9	21.1	20.4	19.7	19.0	18.4	17.8	17.3	16.8	16.3	15.8	15.4	15.0
21.0	32.8	31.1	29.5	28.1	26.8	25.7	24.6	23.6	22.7	21.8	21.1	20.3	19.6	19.0	18.4	17.8	17.3	16.8	16.4	15.9	15.5
22.0	34.0	32.2	30.5	29.1	27.7	26.5	25.4	24.4	23.4	22.5	21.7	21.0	20.3	19.6	19.0	18.4	17.9	17.4	16.9	16.4	16.0

* The Basic Energy Use obtained from this table is to be used in with the Climate Zone Factor in Table 6-11 to calculate the BEU for Storage Heat Pump Water Heaters as shown below.

________	x	________	=	________
Basic Energy Use (from Table 6-8C above)		Climate Zone Factor (from Table 6-11)		Basic Energy Use (to Line 2a, DHW-1)

Table 6-8D – Basic Energy Use (BEU) - Instantaneous Gas or Electric Heaters [no interpolation]

	Pilot Energy (Btu/Hour)												
Recovery Energy	200	250	300	350	400	450	500	550	600	650	700	750	800
3.0	4.8	5.2	5.6	6.1	6.5	6.9	7.4	7.8	8.3	8.7	9.1	9.6	10.0
3.2	5.0	5.4	5.8	6.3	6.7	7.1	7.6	8.0	8.5	8.9	9.3	9.8	10.2
3.4	5.2	5.6	6.0	6.5	6.9	7.3	7.8	8.2	8.7	9.1	9.5	10.0	10.4
3.6	5.4	5.8	6.2	6.7	7.1	7.5	8.0	8.4	8.9	9.3	9.7	10.2	10.6
3.8	5.6	6.0	6.4	6.9	7.3	7.7	8.2	8.6	9.1	9.5	9.9	10.4	10.8
4.0	5.8	6.2	6.6	7.1	7.5	7.9	8.4	8.8	9.3	9.7	10.1	10.6	11.0
4.2	6.0	6.4	6.8	7.3	7.7	8.1	8.6	9.0	9.5	9.9	10.3	10.8	11.2
4.4	6.2	6.6	7.0	7.5	7.9	8.3	8.8	9.2	9.7	10.1	10.5	11.0	11.4
4.6	6.4	6.8	7.2	7.7	8.1	8.5	9.0	9.4	9.9	10.3	10.7	11.2	11.6
4.8	6.6	7.0	7.4	7.9	8.3	8.7	9.2	9.6	10.1	10.5	10.9	11.4	11.8
5.0	6.8	7.2	7.6	8.1	8.5	8.9	9.4	9.8	10.3	10.7	11.1	11.6	12.0
5.2	7.0	7.4	7.8	8.3	8.7	9.1	9.6	10.0	10.5	10.9	11.3	11.8	12.2
5.4	7.2	7.6	8.0	8.5	8.9	9.3	9.8	10.2	10.7	11.1	11.5	12.0	12.4
5.6	7.4	7.8	8.2	8.7	9.1	9.5	10.0	10.4	10.9	11.3	11.7	12.2	12.6
5.8	7.6	8.0	8.4	8.9	9.3	9.7	10.2	10.6	11.1	11.5	11.9	12.4	12.8
6.0	7.8	8.2	8.6	9.1	9.5	9.9	10.4	10.8	11.3	11.7	12.1	12.6	13.0
6.2	8.0	8.4	8.8	9.3	9.7	10.1	10.6	11.0	11.5	11.9	12.3	12.8	13.2
6.4	8.2	8.6	9.0	9.5	9.9	10.3	10.8	11.2	11.7	12.1	12.5	13.0	13.4
6.6	8.4	8.8	9.2	9.7	10.1	10.5	11.0	11.4	11.9	12.3	12.7	13.2	13.6
6.8	8.6	9.0	9.4	9.9	10.3	10.7	11.2	11.6	12.1	12.5	12.9	13.4	13.8
7.0	8.8	9.2	9.6	10.1	10.5	10.9	11.4	11.8	12.3	12.7	13.1	13.6	14.0
7.2	9.0	9.4	9.8	10.3	10.7	11.1	11.6	12.0	12.5	12.9	13.3	13.8	14.2
7.4	9.2	9.6	10.0	10.5	10.9	11.3	11.8	12.2	12.7	13.1	13.5	14.0	14.4
7.6	9.4	9.8	10.2	10.7	11.1	11.5	12.0	12.4	12.9	13.3	13.7	14.2	14.6
7.8	9.6	10.0	10.4	10.9	11.3	11.7	12.2	12.6	13.1	13.5	13.9	14.4	14.8
8.0	9.8	10.2	10.6	11.1	11.5	11.9	12.4	12.8	13.3	13.7	14.1	14.6	15.0
8.2	10.0	10.4	10.8	11.3	11.7	12.1	12.6	13.0	13.5	13.9	14.3	14.8	15.2
8.4	10.2	10.6	11.0	11.5	11.9	12.3	12.8	13.2	13.7	14.1	14.5	15.0	15.4
8.6	10.4	10.8	11.2	11.7	12.1	12.5	13.0	13.4	13.9	14.3	14.7	15.2	15.6
8.8	10.6	11.0	11.4	11.9	12.3	12.7	13.2	13.6	14.1	14.5	14.9	15.4	15.8
9.0	10.8	11.2	11.6	12.1	12.5	12.9	13.4	13.8	14.3	14.7	15.1	15.6	16.0
9.2	11.0	11.4	11.8	12.3	12.7	13.1	13.6	14.0	14.5	14.9	15.3	15.8	16.2
9.4	11.2	11.6	12.0	12.5	12.9	13.3	13.8	14.2	14.7	15.1	15.5	16.0	16.4
9.6	11.4	11.8	12.2	12.7	13.1	13.5	14.0	14.4	14.9	15.3	15.7	16.2	16.6
9.8	11.6	12.0	12.4	12.9	13.3	13.7	14.2	14.6	15.1	15.5	15.9	16.4	16.8
10.0	11.8	12.2	12.6	13.1	13.5	13.9	14.4	14.8	15.3	15.7	16.1	16.6	17.0
10.2	12.0	12.4	12.8	13.3	13.7	14.1	14.6	15.0	15.5	15.9	16.3	16.8	17.2
10.4	12.2	12.6	13.0	13.5	13.9	14.3	14.8	15.2	15.7	16.1	16.5	17.0	17.4
10.6	12.4	12.8	13.2	13.7	14.1	14.5	15.0	15.4	15.9	16.3	16.7	17.2	17.6
10.8	12.6	13.0	13.4	13.9	14.3	14.7	15.2	15.6	16.1	16.5	16.9	17.4	17.8
11.0	12.8	13.2	13.6	14.1	14.5	14.9	15.4	15.8	16.3	16.7	17.1	17.6	18.0
11.5	13.3	13.7	14.1	14.6	15.0	15.4	15.9	16.3	16.8	17.2	17.6	18.1	18.5
12.0	13.8	14.2	14.6	15.1	15.5	15.9	16.4	16.8	17.3	17.7	18.1	18.6	19.0
12.5	14.3	14.7	15.1	15.6	16.0	16.4	16.9	17.3	17.8	18.2	18.6	19.1	19.5
13.0	14.8	15.2	15.6	16.1	16.5	16.9	17.4	17.8	18.3	18.7	19.1	19.6	20.0
13.5	15.3	15.7	16.1	16.6	17.0	17.4	17.9	18.3	18.8	19.2	19.6	20.1	20.5
14.0	15.8	16.2	16.6	17.1	17.5	17.9	18.4	18.8	19.3	19.7	20.1	20.6	21.0
14.5	16.3	16.7	17.1	17.6	18.0	18.4	18.9	19.3	19.8	20.2	20.6	21.1	21.5
15.0	16.8	17.2	17.6	18.1	18.5	18.9	19.4	19.8	20.3	20.7	21.1	21.6	22.0
15.5	17.3	17.7	18.1	18.6	19.0	19.4	19.9	20.3	20.8	21.2	21.6	22.1	22.5
16.0	17.8	18.2	18.6	19.1	19.5	19.9	20.4	20.8	21.3	21.7	22.1	22.6	23.0
16.5	18.3	18.7	19.1	19.6	20.0	20.4	20.9	21.3	21.8	22.2	22.6	23.1	23.5
17.0	18.8	19.2	19.6	20.1	20.5	20.9	21.4	21.8	22.3	22.7	23.1	23.6	24.0
17.5	19.3	19.7	20.1	20.6	21.0	21.4	21.9	22.3	22.8	23.2	23.6	24.1	24.5
18.0	19.8	20.2	20.6	21.1	21.5	21.9	22.4	22.8	23.3	23.7	24.1	24.6	25.0
18.5	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.6	25.1	25.5
19.0	20.8	21.2	21.6	22.1	22.5	22.9	23.4	23.8	24.3	24.7	25.1	25.6	26.0

Instructions for Instantaneous Gas Water Heaters:

1. Calculate: __________________ / __________________________ = ______________________

Adjusted Recovery Load (from line 1e, DHW 1) / Recovery Efficiency (fraction) = Recovery Energy

2. Find Basic Energy Use from table using Recovery Energy (Step 1) and Pilot Btu/hr (DHW-1, line F)
Use nearest table values. At mid-point use higher value. **Do not interpolate.**

3. Enter Basic Energy Use in Line 2a of DHW-1

Instructions for Instantaneous Electric Water Heaters:

1. Calculate: [_________________] / _______________________ x 3 = ___________________

Adjusted Recovery Load (from line 1e, DHW-1) / Energy Factor (from line D, DHW-1) x 3 = Basic Energy Use (to line 2a, DHW-1)

2. Enter Basic Energy Use on Line 2a of Worksheet DHW-1.

Note: For instantaneous electric water heaters, Energy Factor equals Recovery Efficiency.

Table 6-8E – Jacket Loss (Indirect Gas)

Tank Volume (Gallons)	Storage Tank Insulation R-value												
	12	13	14	15	16	17	18	20	22	24	26	28	30
0-19	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8
20-29	1.5	1.4	1.3	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0	0.9	0.9
30-39	1.7	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.1	1.0	1.0
40-49	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.1
50-59	2.0	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1
60-69	2.2	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.2	1.2
70-79	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.3
80-89	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3
90-99	2.6	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4
100-119	2.8	2.6	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4
120-139	3.0	2.8	2.7	2.5	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5
140-159	3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.2	2.0	1.9	1.8	1.7	1.6
160-179	3.5	3.3	3.1	2.9	2.7	2.6	2.5	2.3	2.1	2.0	1.9	1.8	1.7
180-199	3.7	3.4	3.2	3.1	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8
200-249	4.0	3.8	3.5	3.3	3.2	3.0	2.9	2.6	2.4	2.3	2.2	2.0	1.9
250-299	4.5	4.2	3.9	3.7	3.5	3.3	3.2	2.9	2.7	2.5	2.4	2.2	2.1
300-349	4.9	4.6	4.3	4.1	3.8	3.6	3.5	3.2	2.9	2.7	2.6	2.4	2.3
350-399	5.3	5.0	4.7	4.4	4.1	3.9	3.7	3.4	3.2	2.9	2.8	2.6	2.5
400-449	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.7	3.4	3.1	2.9	2.8	2.6
450-499	6.1	5.7	5.3	5.0	4.7	4.5	4.3	3.9	3.6	3.3	3.1	2.9	2.8
500-1000	8.0	7.4	6.9	6.5	6.1	5.8	5.5	5.0	4.6	4.3	4.0	3.7	3.5
1000	9.5	8.8	8.2	7.7	7.2	6.8	6.5	5.9	5.4	5.0	4.7	4.4	4.1

Instructions:

1. No interpolation allowed.
2. Using total insulation R-value (DHW-3, line 3) and tank volume (DHW-3, line 4), find jacket loss.
3. Enter jacket loss (JL) on line 7, DHW-3.

Table 6-9 – Solar Fractions Table

	Conditioned Floor Area (ft^2)																				
Solar Energy Factors	726 to 774	775 to 824	825 to 874	875 to 924	925 to 974	975 to 1049	1050 to 1149	1150 to 1249	1250 to 1349	1350 to 1449	1450 to 1549	1550 to 1649	1650 to 1749	1750 to 1849	1850 to 1949	1950 to 2049	2050 to 2149	2150 to 2249	2250 to 2349	2350 to 2499	≥2500
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.1	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09
1.2	0.29	0.28	0.28	0.27	0.26	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16
1.3	0.40	0.39	0.38	0.37	0.37	0.36	0.35	0.34	0.32	0.31	0.30	0.29	0.28	0.27	0.27	0.26	0.25	0.24	0.24	0.23	0.22
1.4	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.40	0.39	0.37	0.36	0.35	0.34	0.33	0.32	0.31	0.30	0.29	0.29	0.27
1.5	0.57	0.56	0.55	0.54	0.53	0.52	0.50	0.48	0.47	0.45	0.44	0.42	0.41	0.40	0.38	0.37	0.36	0.35	0.34	0.33	0.32
1.6	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.55	0.53	0.51	0.49	0.47	0.46	0.45	0.43	0.42	0.41	0.40	0.38	0.37	0.36
1.7	0.70	0.69	0.68	0.67	0.65	0.64	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.49	0.47	0.46	0.45	0.43	0.42	0.41	0.40
1.8	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.53	0.51	0.50	0.48	0.47	0.46	0.44	0.43
1.9	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.66	0.64	0.62	0.60	0.58	0.56	0.55	0.53	0.51	0.50	0.49	0.47	0.45
2.0	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.65	0.63	0.61	0.59	0.58	0.56	0.54	0.53	0.51	0.50	0.48
2.1	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.66	0.64	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50
2.2	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63	0.61	0.59	0.58	0.56	0.54	0.52
2.3	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63	0.61	0.60	0.58	0.56	0.54
2.4	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63	0.62	0.60	0.58	0.56
2.5	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63	0.62	0.60	0.58
2.6	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63	0.61	0.59
2.7	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.66	0.65	0.63	0.60
2.8	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.66	0.64	0.62
2.9	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.67	0.65	0.63
3.0	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.67	0.64
3.1	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.65
3.2	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.66
3.3	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.67
3.4	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.68
3.5	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69
>3.5	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Table 6-10 – Wood Stove Boiler Credit Factors

	Credit Factors	
Climate Zone	**With Pump**	**Without Pump**
1	0.225	0.250
2	0.225	0.250
3	0.225	0.250
4	0.135	0.150
5	0.135	0.150
6	0.090	0.100
7	0.090	0.100
8	0.045	0.050
9	0.090	0.100
10	0.045	0.050
11	0.090	0.100
12	0.135	0.150
13	0.090	0.100
14	0.090	0.100
15	0.000	0.000
16	0.270	0.300

Table 6-11 – Climate Zone Factors

Climate Zone	Climate Zone Factor
1, 14	1.04
2, 3	0.99
4, 5, 12	1.07
6-11, 13, 15	0.92
16	1.50

6.4 Case Studies

This Part explains how to demonstrate water-heating compliance for a number of common and unusual water heating systems.

Example 6-1 – Single Family, Gas Water Heater

Single family residence with one non-recirculating 40-gallon gas water heater.

This qualifies as a standard water heating system and complies automatically. No water heating calculations are required, although they may be performed to take credit for a particularly efficient water heater. See also Section 6.6.

Example 6-2 – Single Family, Heat Pump Water Heater

Single family residence with one non-recirculating 40-gallon heat pump water heater (EF=1.9) in Climate Zone 12.

Since the minimum EF for a heat pump water heater is 1.8 as shown in Table 3-14, and this system meets that and all other requirements, it qualifies as a standard water heating system and complies automatically. No water heating calculations are required, although they may be completed at the option of the person submitting compliance documentation. See also Section 6.6.

Example 6-3 – Single Family, Two Gas Storage Tank Water Heaters

1,800 ft^2 single family residence with two identical 30-gallon gas storage tank water heaters and a point of use distribution system.

Water heating calculations are required for this system, including forms DHW-1 and DHW-2A. Form DHW-1 calculates Proposed Energy Use for the single water heater type. Credit for the Point of Use distribution system is also included on Form DHW-1. Form DHW-2A calculates the building's combined Total Proposed Energy Use for water heating, and compares it against the building's Standard Energy Use for water heating.

Example 6-4 – Single Family, Three Gas Storage Tank Water Heaters

6,000-ft^2 single family residence with 3 storage gas water heaters (40 gallon, 30 gallon and a 100-gallon unit with 80,000 Btuh input).

Water heating calculations are required for this system, including forms DHW-1, DHW-2A and DHW-3. Form DHW-1 calculates Proposed Energy Use for each individual water heater. Form DHW-3 calculates the Basic Energy Use factor for the 100-gallon water heater because its input is greater than 75,000 Btuh. Form DHW-2A calculates the building's combined Total Proposed Energy Use for the three water heaters, and compares it against the building's Standard Energy Use for water heating.

Note: Because the total floor area is greater than 2,500-ft^2, the Standard Recovery Load and Standard Energy Use for the building from Table 6-5 equal that for a 2,500-ft2 house.

Example 6-5 – Multi-family, Separate Gas Water Heaters for each Unit

10-unit multi-family building with separate gas water heaters for each dwelling unit. Five units have 30-gallon water heaters, and five units have 50-gallon water heaters.

Water heating calculations are not required if each system is non-recirculating because each dwelling unit has a standard water heating system.

Example 6-6 – Multi-family, Temperature Controlled Recirculation System

8-unit, 7,800-ft^2 multi-family building with a 200-gallon storage gas water heater and temperature controlled recirculation system serving all units.

Water heating calculations are required for this system, including forms DHW-1, DHW-2B and DHW-3.

In this situation, the correct approach is to use Form DHW-2B to calculate the average size of each dwelling unit within the building and the basic energy use per average unit.

Because a 200 gallon water heater has an input rating over 75,000 Btuh, it is necessary to use Form DHW-3 to calculate its Basic Energy Use for insertion on Line 12b of Form DHW-2B.

DHW-1 compares Proposed Energy Use to Standard Energy Use for the average dwelling unit. The Proposed Energy Use includes a penalty for the recirculation system with temperature controls.

Example 6-7 – Single Family Addition, Replacing Existing Water Heating System

Existing 1,500 ft^2 single family residence with 500 ft^2 addition. A new 50-gallon gas storage tank water heater will replace the existing water heating system.

Since this is an alteration to an existing water heating system, no water heating calculations are required. Building energy compliance for the addition may be demonstrated for either the addition alone or for the existing-plus-addition.

Example 6-8 – Single Family Existing, New Instantaneous Gas Water Heater

Existing 2,000-ft2 single family residence with one 50-gallon gas water heater; a 600 ft^2 addition with a new instantaneous gas water heater is proposed.

When there is an increase in the number of water heaters with an addition, the *Standards* allow addition alone compliance in certain circumstances. Since this is an instantaneous gas water heater, if it can be demonstrated that it uses no more energy than a 50-gallon gas non-recirculating storage tank (see Table 6-2), then no water heating calculations are submitted.

Another alternative is to show existing-plus-addition compliance.

Default assumptions are used for the existing water heater. For the existing-plus-addition portion of the analysis, a second Form DHW-1 calculates water heater type, and Form DHW-2A calculates the building's combined Total Proposed Energy Use, and compares it against the whole building's Standard Energy Use.

Note: For instantaneous gas water heaters, Recovery Energy must be calculated using the instructions at the end of Table 6-8D before finding Basic Energy Use.

Example 6-9 – Single Family, Non-recirculating Gas Water Heater

Single family residence with one non-recirculating 50 gallon gas water heater. The water heater has an input rating of 76,000 Btu/hr.

Even though this water heater has an input rating greater than 75,000 Btu/hr, it still qualifies as a standard water heater because it is a storage gas heater of 50 gallons or less. The system still qualifies as a standard water heating system because it meets all of the stated requirements. No water heating calculations are required, and the system complies automatically. See also Section 6.6.

Example 6-10 – Single Family, Existing+Addition, Electric Water Heater

Existing single family residence with one electric water heater; a 500 ft^2 addition with a 30-gallon electric water heater is proposed.

When there is an increase in the number of water heaters with an addition, the *Standards* allow addition alone compliance in certain circumstances. If this residence does not have natural gas connected to the building and the new water heater has an EF of 0.90 or greater, the system automatically complies (see 7.2.4). No water heating calculations are submitted.

Example 6-11 – Single Family, Replacement Gas Water Heater

A single family residence with one gas water heater is replacing the water heater with a new gas water heater.

This system must comply with the mandatory requirements for alterations. This includes a certified water heater and pipe insulation on the first five feet of hot and cold water pipes. Since compliance with the annual water heating budget is not required, no water heating calculations are required.

Example 6-12 – Residential Building, Gas to Electric Water Heater

A residential building is replacing a gas water heating system with an electric water heating system.

In addition to complying with mandatory requirements mentioned in Example 6-11, changing from gas to electric is prohibited (see Section 7.5) unless it “can be demonstrated that the source energy use of the new system is more efficient than the existing system.”

Alterations can also show compliance using an “existing-plus-alteration” compliance approach, as explained in Section 7.5. This approach could be used to take credit for improvements to the building being made to offset the water heating changes.

6.5 Combined Hydronic Space and Water Heating

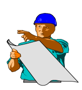
Section 8.8 explains hydronic space heating systems. When such a system serves the additional function of providing domestic hot water, the system is analyzed for its water heating performance as if the space heating function were separate. In other words, treat any hydronic system used for water heating the same as any other water heating system: Input the correct water heater type, auxiliary input credit (if any) and specify the distribution system on DHW-1.

The DHW-5 is used to calculate an effective AFUE or to adjust the AFUE for pipe losses when a space heating boiler is also used for water heating (see Section 6.3).

Complete the DHW-5 worksheet for any project that includes a hydronic space heating system, combined hydronic space and water heating system, or boiler (see Section 6.3). This worksheet should accompany all necessary water heating compliance worksheets. The DHW-5 worksheet is used to determine the Effective AFUE for storage gas water heaters and the Effective HSPF for storage electric and heat pump water heaters used to supply energy for the combined hydronic space and water heating system.

For performance compliance, the water heating worksheets are not printed, but the inputs will appear on the C-2R and CF-1R forms.

6.6 System Descriptions



The water heating calculation method evaluates water heating systems by analyzing the following system components: Water Heaters, Auxiliary Systems, and Distribution Systems. Separate calculations are required for Hydronic Space and Water Heating Systems. This part describes all of the system types that fall within each category, and explains installation criteria.

Water Heaters

This part describes water heater types that can be analyzed using the water heating method:

- Standard Water Heater
- Storage Gas
- Large Storage Gas
- Storage Electric
- Storage Heat Pump
- Instantaneous Gas
- Instantaneous Electric
- Indirect Gas

All water heaters must be certified (see Section 1.6). This guarantees that they meet the minimum requirements of the National Efficiency Standards and State Efficiency Standards as described in the California Appliance Efficiency Regulations.

For small storage gas water heaters this corresponds to an Energy Factor = 0.62 - (0.0019 x Volume).

For small storage electric water heaters the minimum is an Energy Factor = 0.93 - (0.00132 x Volume).

Standard Water Heater

A standard water heater is one that automatically complies with the *Standards*, since its characteristics meet the installation criteria described below. For a system in a single family dwelling consisting of a single standard water heater and a standard distribution system, compliance is demonstrated by listing water heater type and distribution system on form CF-1R. No other water heating calculations are required.

Installation Criteria:

One gas water heater of 50-gallons capacity or less per dwelling unit. On any unit with an EF of less than 0.58, R-12 external insulation is mandatory.

Storage Gas

A gas water heater designed to heat and store water at less than 180°F. Water temperature is controlled with a thermostat. Storage gas water heaters have a manufacturer's specified storage capacity of at least two gallons and less than 75,000 Btuh input.

Large Storage Gas

A storage gas water heater with greater than 75,000 Btuh input.

Storage Electric

An electric water heater designed to heat and store water at less than 180 °F. Water temperature is controlled with a thermostat. Storage electric water heaters have a manufacturer's specified storage capacity of at least two gallons.

Storage Heat Pump

An electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water. It includes all necessary auxiliary equipment such as fans, storage tanks, pumps or controls. EFs for heat pump water heaters are found in the Commission's Directory of Certified Water Heaters.

Instantaneous Gas

A gas water heater controlled manually or automatically by a water flow activated control or a combination of water flow and thermostatic controls, with a manufacturer's specified storage capacity of less than two gallons.

Recovery efficiency and pilot energy are in the Commission’s database of certified water heaters.

Instantaneous Electric

An electric water heater controlled automatically by a thermostat, with a manufacturer's specified storage capacity of less than two gallons.

Note: Instantaneous water heaters are not generally designed for use with solar water heating systems or as heat sources for indirect fired water heaters. They are also typically inappropriate for use with recirculation systems. Consult manufacturer's literature when considering these applications.

Indirect Gas

A water heater consisting of a storage tank with no heating elements or combustion devices, connected via piping and recirculating pump to a heat source consisting of a gas or oil fired boiler, or instantaneous gas water heater (see note following the definitions of Instantaneous Gas and Electric).

Installation Criteria:

The storage tank must be insulated in accordance with §150(j)1.B. of the *Standards*, which requires a factory-installed minimum of R-16 (labeled on outside of tank) or a minimum of R-12 external insulation (see Section 2.6).

The piping connecting the heating source and the storage tank must be insulated to R-4 for pipe less than or equal to 2 inches in diameter, and to R-6 for pipes larger than 2 inches in diameter. This includes any piping located in concrete slabs or underground.

External Tank Insulation

Insulation applied to the exterior of storage type water heater tanks.

When installed, water heater insulation should be applied to completely cover the exterior sides of water heaters, but should not conceal controls or access ports to burners, cover combustion air openings, or interfere in any way with safe water heater operation. Insulation of top and bottom surfaces is not necessary.

External tank insulation is mandatory for water heaters with less than 0.58 EF, and for unfired water heater tanks that do not have R-16 internal insulation (as indicated on the outside of the tank).

Auxiliary Systems

Auxiliary systems add hot water to the overall water heating system through means other than the typical water heaters defined above.

The Water Heating Calculation Method allows water heating credits for three auxiliary systems which save energy by using nondepletable resources as energy sources. These systems – Passive and Active Solar Water Heaters and Wood Stove Boilers – are described below.

Passive Solar Water Heaters

Systems which collect and store solar thermal energy for domestic water heating applications and do not require electrical energy input for recirculating water through a solar collector.

Installation Criteria:

Passive solar water heaters (including integral and thermosyphon) must be tested in accordance with Solar Rating & Certification Corporation (SRCC) Standard 300-98

SRCC's address is:

Solar Rating and Certification Corporation
C/o FSEC, 1679 Clearlake Road
Cocoa, FL 32922-5703
(407) 638-1537
(407) 638-1010 (FAX)

Active Solar Water Heaters

Systems which collect and store solar thermal energy for domestic water heating applications requiring electrical energy input for operation of pumps or other components.

Installation Criteria:

Flat plate collectors used with active solar waters must be tested in accordance with SRCC Standard 300-98 (see address above). Alternatively Flat plate collector ratings tested in accordance with SRCC Standard 100-81 may be used if F-chart is used to determine the systems Solar Fraction.

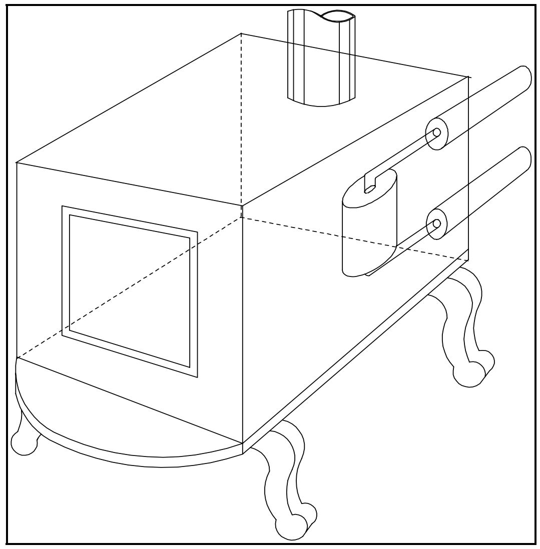
Wood Stove Boilers

Wood stoves equipped with heat exchangers for heating domestic hot water (see Figure 6-3).

Installation Criteria:

Energy credits may only be taken when the building department having jurisdiction has determined that natural gas is not available.

Figure 6-3 – Wood Stove Boiler



A tempering valve must be installed at the outlet of the water heater to prevent scalding.

A pressure-temperature relief valve must be installed at the wood stove.

The wood stove boiler must be properly sized to minimize the amount of excess hot water produced by the unit.

All health and safety codes, including codes applying to pressurized boiler vessels, must be met.

Distribution Systems

The water heating distribution system is the configuration of piping, pumps and controls that regulates delivery of hot water from the water heater to all end uses within the building.

All criteria listed below are based on Commission contract #400-88-003, *Residential Water Heating Study*: March 31, 1991.

The water heating calculation method gives credits for especially energy-efficient distribution systems, while taking penalties for less energy-efficient systems. The distribution systems that may be analyzed are:

- Standard Distribution System
- Point of Use
- Hot Water Recovery
- Pipe Insulation
- Parallel Piping
- Recirculation: Continuous
- Recirculation: Temperature Controlled
- Recirculation: Time Controlled
- Recirculation: Time & Temperature Controlled
- Recirculation: Demand Pumping
- Hot Water Recovery + Recirculation: Demand Pumping
- Pipe Insulation + Recirculation: Demand Pumping

Only one distribution system type may be chosen for each water heating system, with the exception of recirculation systems with demand pumping which may be combined with **either** hot water recovery systems **or** pipe insulation. In either of these cases the two appropriate adjustment values from Table 6-6 are added together and input as Distribution Credit on form DHW-1.

Pipe insulation is required for all other recirculation systems (except Demand) and may not be used for extra credit (see Section 2.6).

Standard Distribution System

A standard distribution system does not incorporate a pump for recirculation of hot water, and does not take credit for any design features eligible for energy credits. A distribution system normally eligible for energy credits, such as one with pipe insulation, may be modeled as standard (i.e., no credits) to avoid the need for any water heating calculations.

Compliance for any water heating system in a single family house with standard distribution and only one standard water heater is demonstrated by listing the water heater type and distribution system on form CF-1R. No other water heating forms are required.

Installation Criteria:

No pumps may be used to recirculate hot water. The first five feet of hot and cold water piping adjacent to the water heater must be insulated with minimum R-4 insulation (see Section 2.6).

Point of Use

A distribution piping system that limits hot water distribution system heat loss by minimizing the distance between the water heater and hot water fixtures.

Credit for only one Point of Use may be taken even if additional water heaters meeting the criteria will be installed.

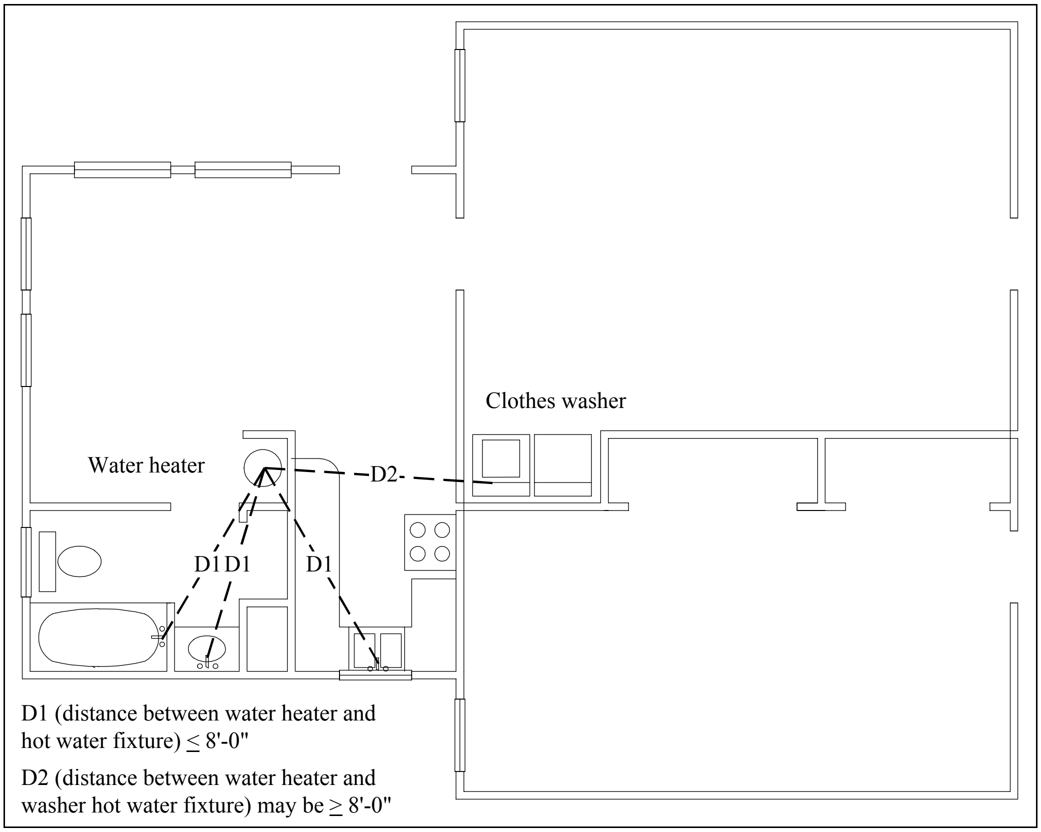
Installation Criteria:

The distance between the water heater and any hot water fixture cannot exceed eight feet, measured in plan view (see Figure 6-4).

All water heaters and hot water fixtures must be shown on plans submitted for local building department plan check.

EXCEPTION: Washing machines for clothing may be located more than eight feet from the water heater.

Figure 6-4 – Point of Use



Hot Water Recovery System

A distribution system that includes a device that reclaims hot water from the distribution piping by drawing it back to the water heater or other insulated storage vessel.

Installation Criteria:

Hot water recovery systems (HWR) must be plumbed such that a positive supply of cold water from the water supply main is provided to the appropriate connection on the device.

Hot water recovery systems must be connected to each water heater serving individual dwelling units.

Credit for only one HWR may be taken even though more than one may be installed or specified in the building plans.

Credit may not be taken for a HWR in a multi-family central water heating system serving multiple dwelling units.

Hot water recovery systems may be used for credit in recirculation systems with demand pumping.

Pipe Insulation

Table 6-6 lists credits that may be taken for insulation of water mains in addition to insulation required by §150 of the *Standards* (first five feet from water heater). The pipe insulation credit is only allowed for 3/4 inch or larger, non-recirculating hot water mains and Demand Recirculating Systems.

Installation Criteria:

R-value of applied insulation must not be less than R-4.0, or less than R-6.0 for pipe diameters greater than 2 inches. No additional credit may be taken for R-4 or R-6 insulation, respectively (see Section 2.6.3).

Pipe insulation may only be used for credit in recirculation systems with demand pump. *Pipe insulation is required for all other recirculation systems and is not eligible for credit.*

Note: Heat tape – electric resistance heating tape wrapped around hot water pipes – may be used only for freeze protection and cannot be used instead of mandatory pipe insulation (see Section 2.6.3) or pipe insulation receiving distribution credit.

Parallel Piping

A distribution system that limits the amount of heat loss and water lost from the distribution piping by minimizing the volume of hot water left in the pipes at the end of each water draw.

Credit for Parallel Piping can only be used if each hot water use location (each kitchen, each bathroom and each laundry area) has a separate distribution line with a maximum size of half-inch pipe run from the location of the water heater to each hot water use location.

Installation Criteria:

Adequate distribution piping must be supplied to meet the demand at each hot water use location as required by the plumbing code. No piping over one-half inch may be used with the exception of a manifold located within six feet of the water heater to which the half-inch piping runs are connected.

All water heaters, distribution line runs and fixture points must be shown on the plans.

Recirculation System

Continuous distribution system using a pump to recirculate hot water to branch piping though a looped hot water main with no control of the pump, such that water flow is continuous.

Installation Criteria:

All piping used to recirculate hot water must be insulated with R-4 insulation or equivalent. This includes any recirculating piping located in concrete slabs or underground. Since the *Standards* require this insulation, it is not eligible for the Pipe Insulation credit.

Recirculation System: Temperature Controlled

Recirculation system that uses temperature controls to cycle pump operation to maintain circulated water temperatures within certain limits.

Installation Criteria:

All criteria listed for continuous recirculation systems apply.

An automatic thermostatic control must be installed to cycle the pump on and off in response to the temperature of water returning to the water heater through the recirculation piping. Minimum differential or "deadband" of the control shall not be less than 20°F.

Plans must indicate pump and control manufacturer, model number and temperature settings.

Recirculation System: Time Controlled

Recirculation system that uses a timer control to cycle pump operation based on time of day.

Installation Criteria:

All criteria listed for continuous recirculation systems apply.

A timer must be permanently installed to regulate pump operation. Timer setting must permit the pump to be cycled off for at least eight hours per day.

Plans must indicate pump and timer manufacturer and model number.

Recirculation System: Time and Temperature Controlled

Recirculation system that uses both temperature and timer controls to regulate pump operation.

Installation Criteria:

All criteria listed for continuous, temperature controlled, and timer controlled recirculation systems apply.

Recirculation System: Demand Pumping

Recirculation system that uses brief pump operation to recirculate hot water to fixtures on demand.

Installation Criteria:

All criteria listed for continuous recirculation systems apply, except that pipe insulation is not required.

Pump start-up must be provided by one or more momentary contact switches, or a hot water flow sensing device located at the water heater. Systems using momentary contact switches must have at least one switch at each floor level, one of which must be located at the kitchen sink.

Pump shut-off must be provided by either a temperature sensing device that shuts off the pump when the pipe is full of hot water, or by a timer which limits pump run time to two minutes or less.

Plans must include a wiring/circuit diagram, and manufacturer/model numbers for the pump and timer/temperature sensing device.

Demand systems can only be used for control of pumps serving one dwelling unit. They are not used for central systems in multi-family buildings.

Note: In an exception to the rule that distribution systems may not be combined, insulation *or* hot water recovery systems may be used for credit in recirculation systems with demand pumping (see below). Pipe insulation is required for all other recirculation systems, so it is not eligible for extra credit.

Recirculation systems are not used with instantaneous water heaters.

Hot Water Recovery + Recirculation System: Demand Pumping

This combination system receives both credits explained under each system, separately, above. Installation criteria for both credits – hot water recovery and demand recirculation – apply to this combined distribution type.

Pipe Insulation + Recirculation System: Demand Pumping

This combination system receives both credits explained under each system, separately, above. Installation criteria for both credits – pipe insulation and demand recirculation – apply to this combined distribution type.

Hydronic Space and Water Heating

Combined Hydronic Space and Water Heating

A combined water and space heating system using the same water heater to heat the building and to provide domestic hot water.

Installation Criteria:

Piping for pump recirculating hydronic space heating supply lines must be insulated to R-4 for pipes less than or equal to 2 inches nominal diameter and R-6 for larger pipe diameters.

Dedicated (Separate) Hydronic Space Heating

A system using separate water heaters to provide space heating and domestic hot water, each dedicated to one function.

Installation Criteria:

Piping for pump recirculating hydronic space heating supply lines must be insulated to R-4.0 for pipes 2 inches or less in diameter and to R-6.0 for larger pipe diameters. See the *Standards*, §150(j).

7 Additions and Alterations

Additions, alterations and repairs are common construction projects for California homeowners. The *Standards* apply differently to each.

- An addition is a change to an existing building that increases conditioned floor area and volume. Converting a garage or unheated basement into a conditioned living space, enclosing and conditioning a patio, or building onto a home are all examples of an addition. The prescriptive Package D or the performance requirements apply to the increased floor area as if it is a new building. .
- An alteration is a change to an existing building that is not an addition. An alteration could include a new water heater, heating system, air conditioner, lighting system or a change to the building envelope, such as new window.
- A repair is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. Repairs to low-rise residential buildings are not within the scope of these *Standards*.

The *Standards* apply to both additions and alterations, but not to repairs. The application of the *Standards* is somewhat tricky to additions and alterations because of the need to work around existing conditions. As a result the *Standards* have some special requirements and performance modeling rules for additions and alterations, which are explained in this chapter. The chapter is organized in the following sections:

Compliance Approaches for Additions

Prescriptive Requirements for Additions

Performance Requirements for Additions

Documentation for Additions

Alterations

Repairs

7.1 Compliance Approaches for Additions

Definitions
§101(b)

ADDITION is any change to a building that increases conditioned floor area and conditioned volume. See also, NEWLY CONDITIONED SPACE.

…

NEWLY CONDITIONED SPACE is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semiconditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition. See Section 149 for nonresidential occupancies and Section 152 for residential occupancies.

§152

(a) ***Additions****. Additions to existing residential buildings shall meet the requirements of Sections 111 through 118, Section 150, and either Section 152 (a) 1 or 2.*

EXCEPTION 1 to Section 152 (a): *Existing structures with R-11 framed walls showing compliance with Section 152 (a) 2 (Performance Approach) are exempt from Section 150 (c).*

EXCEPTION 2 to Section 152 (a): *Any dual-glazed greenhouse window and dual-glazed skylight installed in an addition complies with Section 151 (f) 3 A.*

EXCEPTION 3 to Section 152 (a): *If the addition will increase the total number of water heaters in the building, one of the following types of water heaters may be installed to comply with Section 152 (a) 1 or Section 152 (a) 2 A, and Section 152 (c):*

1. *A gas storage nonrecirculating water-heating system that does not exceed 50 gallons capacity; or*
2. *If no natural gas is connected to the building, an electric storage water heater that does not exceed 50 gallons capacity, has an energy factor not less than 0.90; or*
3. *A water-heating system determined by the executive director to use no more energy than the one specified in Item 1 above; or if no natural gas is connected to the building, a water-heating system determined by the executive director to use no more energy than the one specified in Item 2 above.*

For prescriptive compliance with Section 152 (a) 1, the water-heating systems requirement in Section 151 (f) 8 shall not apply. For performance compliance for the addition alone, only the space-conditioning budgets of Section 151 (b) 2 shall be used; the water-heating budgets of Section 151 (b) 1 shall not apply.

The performance approach for the existing building and the addition in Section 152 (a) 2 B may be used to show compliance, regardless of the type of water heater installed.

EXCEPTION 4 to Section 152 (a): *When heating and/or cooling will be extended to an addition from the existing system(s), the existing equipment need not comply with Title 24, Part 6. The heating system capacity must be adequate to meet the minimum requirements of UBC Section 310.11.*

1. ***Prescriptive approach****. Additions to existing buildings shall meet the following additional requirements:*

   A. *Additions up to 100 square feet shall not exceed 50 square feet of glazing, the glazing U-factor shall not exceed 0.75, and the glazing Solar Heat Gain Coefficient shall not exceed the value specified in Alternative Component Package D (Tables 1-Z1 through 1-Z16); or*

   B. *Additions less than 1000 square feet shall meet all the requirements of Package D (Section 151 (f) and Tables 1-Z1 through 1-Z16), except that the addition's total glazing area limit is the maximum allowed in Package D plus the glazing area that was removed by the addition, and the wall insulation value need not exceed R-13.*

   EXCEPTION to Section 152 (a) 1 B: *If an addition is less than 500 square feet, glazing may have a U-factor not to exceed 0.75 in lieu of any lower U-factor required by the package.*

   C. *Additions of 1000 square feet or greater shall meet all the requirements of Package D (Section 151 (f) and Tables 1-Z1 through 1-Z16).*

2. ***Performance approach**. Performance calculations shall meet the requirements of Section 151 (a) through (e), pursuant to either Item A or B, below.*

   A. *The addition complies if the addition alone meets the combined water-heating and space-conditioning energy budgets.*

   B. *The addition complies if the energy efficiency of the existing building is improved such that the source energy consumption of the improved existing building and the addition is equal to or less than that of the unimproved existing building plus an addition that complies with the applicable energy budget.*

…

(c) Electric-resistance water-heating or space-conditioning systems may be installed in or in conjunction with an addition only if the electric-resistance system meets the applicable energy budget(s) from Section 151 (b) pursuant to Section 152 (a) 2.

(d) Any addition or alteration may comply with the requirements of Title 24, Part 6 by meeting the requirements for new buildings for the building as a whole.

7.1.1 Basic Approaches

There are three general approaches for showing that residential additions comply with the *Standards*. For two of these there is a prescriptive and performance option.

1. The first approach is to consider just the addition and ignore the existing house. In this case either the prescriptive or performance standards are applied to the addition alone. It is not necessary to make any improvements to the existing building.
2. The second approach is to use the performance approach to make trade-offs between the addition and the existing house. For instance, ceiling insulation in the existing house might be increased to make up for extra glass in the addition. With this approach you show that energy use for the enlarged house (with improvements to the existing portion) would be no greater than the energy use of the unimproved existing house and an addition that met the prescriptive Package D requirements.
3. The third approach is to treat the project as if it were entirely new construction and apply either the prescriptive or performance approaches to the entire building.

For all three approaches, compliance with mandatory measures is required.

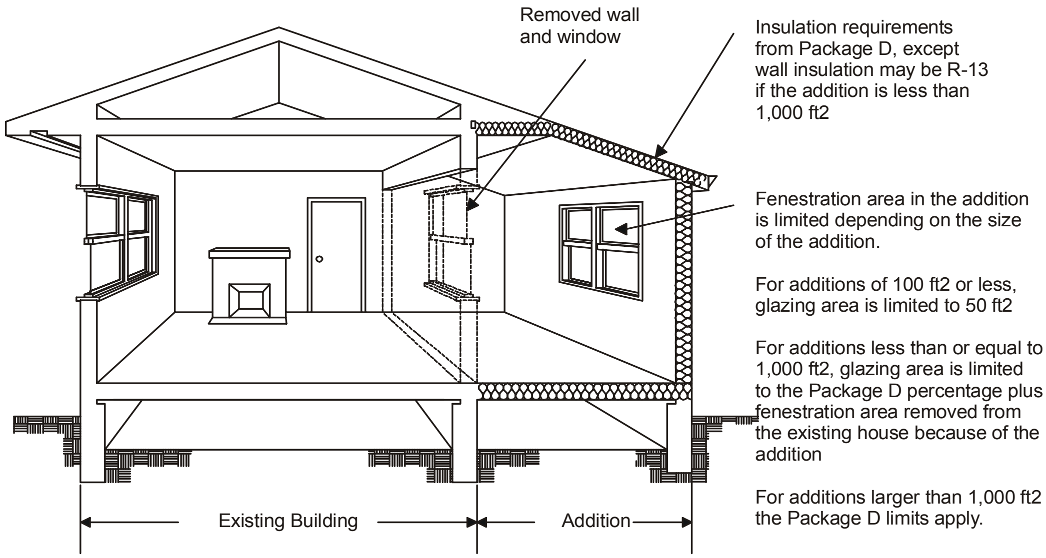
Table 7-1– Comparison of Compliance Methods for Additions

Approach	Prescriptive Method	Performance Method
Addition Alone	Simplest to document. Small additions have less stringent requirements. Limited to Package D. New space-conditioning systems require setback thermostat (exceptions do not apply). Glass area limited depending on the size of the addition (see Table 7-2).	Some flexibility If a non-central space-conditioning system is installed, no setback is required as long as a “no setback” condition is modeled for the proposed design. Allows tradeoffs in efficiency measures (e.g., R-19 ceilings with lower glass U-factor). Can exceed prescriptive limitations on glass.
Existing Plus Addition	Not applicable	Existing structures with R-11 in the framed walls do not have to meet the R-13 mandatory requirement. Same characteristics as noted above for performance compliance of addition alone. Most flexibility. Allows efficiency improvements to the existing structure to compensate for inefficiencies in the addition. Allows credit for energy efficiency improvements made in the past.
New Construction	The easiest compliance method for major renovations and gut rehabilitation projects where the distinction between the existing house and the addition is muddled.	Provides all the advantages of the performance approach for the addition alone and the addition plus existing.

7.1.2 Addition Alone, Prescriptive

Any addition may comply with the applicable prescriptive requirements in Package D. This procedure does not involve the existing structure. The analysis may be performed using either a special prescriptive package according to the size of the addition. Using prescriptive compliance to show compliance for an addition alone is the simplest (although least flexible) approach.

Figure 7-1 – Addition Alone Compliance Approach



7.1.3 Addition Alone, Performance

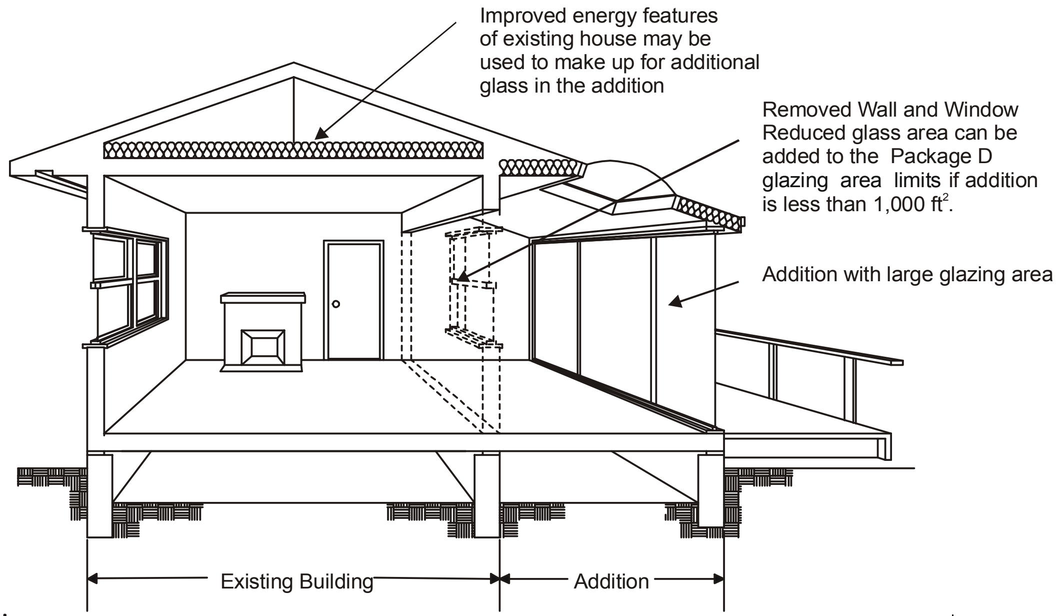
Any addition may be analyzed alone using an approved computer method. Compliance for the addition is the same as showing compliance for a new building[1] (see also Chapter 5). Refer also to the compliance supplement provided by the vendor of the program you're using for further information on modeling additions alone. Analyzing additions alone works well for relatively large additions with moderate window and skylight area. If an addition alone does not comply with the *Standards*, improvements to the existing building may be necessary.

7.1.4 Existing Plus Addition, Performance Only

The most flexible method for showing compliance for an addition is to consider the entire existing building along with the addition. By comparing energy consumption before and after the remodel, credit may be taken for improvements to the energy efficiency features in the existing building. Compliance is shown using an approved computer program. Refer also to the program compliance supplement provided by the program vendor for additional information on modeling additions.

[1] When modeling additions alone, the number of dwelling units is input as the ratio of the addition conditioned floor area to the entire existing house plus addition conditioned floor area. This is needed in order for the internal gains, occupant density and other modeling assumptions to be properly prorated.

Figure 7-2 – Existing House Plus Addition Compliance Approach



7.1.5 New Construction, Prescriptive or Performance

The easiest compliance method for major renovations and gut rehabilitation projects, where the distinction between the existing house and the addition is muddled, is to treat the entire project like it is new construction. This approach has considerable flexibility, but is more stringent than the Existing Plus Addition Method.

7.2 Prescriptive Requirements for Additions

The Package D requirements apply to additions in much the same way that they apply to new buildings. However, some of the building envelope requirements depend on the size of the addition, and there are exceptions for other measures. The prescriptive requirements for additions are summarized in Table 7-2. More detail is provided in the paragraphs that follow.

The Alternative to Package D, which requires more energy efficient windows and space conditioning equipment in lieu of measures that require field verification and diagnostic testing, may also be used with additions (see Table 3-2). This may be a desirable prescriptive option.

Table 7-2 – Prescriptive Requirements for Additions

	Size of Addition			
Component	100 ft² or less (1)	Less than 500 ft² (1)	Less than 1,000 ft² (1)	All Additions (1)
Ceiling Insulation	R-19	Package D (2)	Package D (2)	Package D (2)
Wall Insulation (3)	R-13	R-13	R-13	Package D (2)
Floor Insulation	R-13	Package D (2)	Package D (2)	Package D (2)
Fenestration U- factor (5)	0.75 (10)	0.75 (10)	Package D (2)	Package D (2)
Glazing Area	< 50 ft² (6)	Package + Glass Removed (7)	Package + Glass Removed (7)	Package D (2)
Solar Heat Gain Coefficient (SHGC)	Package D (2)	Package D (2)	Package D (2)	Package D (2)
Radiant Barriers (4)	N/A	Package D (2)	Package D (2)	Package D (2)
Space Heating & Cooling (8)	Mandatory	Package D (2)	Package D (2)	Package D (2)
Refrigerant Charge and Airflow (or TXV) (9)	N/A	Package D (2)	Package D (2)	Package D (2)
Duct Sealing (9)	N/A	Package D (2)	Package D (2)	Package D (2)
Water Heater Replacement	N/A	N/A	N/A	N/A
Add Water Heater	See Table 7-5	See Table 7-5	See Table 7-5	See Table 7-5

Notes:

1. Additions for any specific size range column can also use prescriptive requirements listed in any column to the right as long as all requirements in the chosen column are met.
2. Areas shown in gray are the Package D requirements that apply to additions in the same manner as they apply to new construction. For these requirements, either the standard Package D or the Alternative to Package D may be used (see Table 3-2).
3. "Heavy Mass" and "Light Mass" walls may meet the Package D requirements for mass wall insulation instead of R-13 (see Table 3-1).
4. The radiant barrier requirement only applies to the addition roof area. It is not necessary to retrofit a radiant barrier in the existing attic.
5. Dual-glazed greenhouse windows and dual-glazed skylights are assumed to meet the applicable U-factor requirements.
6. This approach does not allow credit for glass removed. As described in Note 1, compliance with all the requirements for the column for additions of less than 500 square feet is allowed, in which case credit for glazing removed is allowed.
7. Glazing area is limited to the Package D fenestration area plus the area of any glazing removed because of the addition.
8. When heating and/or cooling will be extended to an addition from the existing system(s), the existing equipment need not comply with Title 24, Part 6. The heating system capacity must be adequate to meet the minimum requirements of UBC Section 310.11. No electric resistance space heating may be installed.
9. The requirements for testing refrigerant charge and airflow (or installing a thermostatic expansion valve (TXV)) apply only if a new split system air conditioner or heat pump is installed as part of the addition. If a separate air distribution system is installed for the addition, then this new system must be tested and sealed to have a leakage less than or equal to 6% of the fan airflow. If an existing air distribution system is extended to serve the addition, this too must be tested, but the tested target duct leakage depends on the size of the addition and other factors discussed in Section 7.2.3, Determining the Target Percent Leakage. In lieu of testing duct leakage and refrigerant charge and airflow (or installing and verifying a TXV), the builder can choose to meet the Alternative to Package D requirements. See Table 3-2.
10. When the Alternative to Package D is used for additions of 500 ft² or less, the fenestration U-factor and SHGC criteria of the Alternative to Package D must be met. See Table 3-2 for a summary of the requirements.
11. When replacing a central air conditioner that serves both the addition and existing building, the replacement is an alteration and must meet the requirements described in 7.5.2, New Space Conditioning Equipment.

Example 7-1 – Prescriptive Requirements – Additions Less than 100 ft²

Question

A small addition of 75 ft² is being planned – an existing porch is being covered off a master bedroom. A new duct to be extended from the existing heating and air conditioning system will serve the new conditioned space. The contractor wants to follow the prescriptive requirements. What requirements apply? The house is located in climate zone 7.

Answer

Since the addition is smaller than 100 ft², glass area is limited to a maximum of 50 ft². The glass must have a U-factor of 0.75 or less. At least R-19 roof insulation and R-13 wall insulation must be installed. The new windows must have an SHGC of 0.40 or less. There are no requirements for upgrading the existing heating and cooling system, e.g. no need to retrofit a thermostatic expansion valve (TXV) or to test the refrigerant charge and airflow of the existing unit.

Example 7-2 – Reuse of Windows

Question

If I remove a window from the existing house while doing an addition, can I re-use this window in the addition, or does it need to meet a certain U-factor?

Answer

You can use this existing window in the addition; however, you must use the actual or default U-factor and SHGC of this window in showing compliance. You may not be able to comply with the prescriptive requirements, so performance compliance may be the only option. Window certification and labeling requirements of §116(a) do not apply to used windows.

7.2.1 Mandatory Measures

The mandatory measures apply to all new construction, including additions. For example, if a new space-heating system is being installed in the addition, the equipment must be certified, sizing calculations are required, ducted systems must meet insulation and installation requirements, and a setback thermostat is required. General exceptions apply to many of these requirements (including additions). See Chapter 2.

7.2.2 Envelope Measures

The Package D envelope measures apply to additions in the same way they apply to new construction, however, there are exceptions to some of the requirements as described in Table 7-2

Dual-Glazed Skylights and Greenhouse Windows

Dual-glazed skylights or dual-glazed greenhouse windows are treated as though they have the U-factor required for compliance, regardless of the approach (prescriptive or performance). However, greenhouse windows must meet the Package D SHGC requirements for prescriptive compliance. The U-factor required by Package D should be included in compliance documentation for these fenestration products (or 0.75 for additions of less than 500 square feet). The U-factors to be used in compliance calculations for additions and alterations greater than 500 ft² are shown in Table 7-3. Green house windows add volume, but not floor area to the building and are therefore alterations, not additions, if this is the only change.

Table 7-3 – Double Glazed Skylight and Greenhouse Window U-factors for use in Compliance

Package D		***Alternative to Package D***[1, 2]	
Climate Zones	***U-factor***	***Climate Zones***	***U-factor***
1, 2, 11, 12, 13, 14, 15	0.65	2, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15	0.40
3, 4, 5, 6, 7, 8, 9, 10	0.75		
16	0.60	1, 3, 5, 6, 16	0.55

1 Alternative to Package D is not used in performance calculations.

2 See Table 3-2.

Example 7-3 – Accounting for Greenhouse Windows

Question

For additions that include a greenhouse window or a skylight, what are the U-factor requirements? What is the area used for calculations for greenhouse windows?

Answer

In additions, you can assume that double-glazed greenhouse windows or skylights have the U-factor required to comply with the prescriptive standards and that this U-factor can also be used to determine compliance with performance approaches. However, the actual or default SHGC of greenhouse windows and skylights are used for showing prescriptive or performance compliance. Note, in new construction that is not associated with an existing building, the actual U-factor of fenestration products must be used for compliance documentation/calculations. For greenhouse windows, the window area is the rough opening.

Radiant Barriers

The Package D prescriptive standard requires that radiant barriers be installed in the climate zones that have significant cooling loads (climate zones 2, 4, and 8 through 15). The radiant barrier requirement also applies to additions in these climate zones (except for additions less than 100 ft^2).

Example 7-4 – Radiant Barriers in Additions

Question

Where do radiant barriers need to be installed when using the prescriptive Package D or meeting the performance standards where no credit is taken for retrofitting a radiant barrier in the existing house?

Answer

The radiant barrier only needs to be installed on the underside of the roof assembly associated with the addition.

7.2.3 Space Conditioning Measures

In general, the space heating or cooling requirements only apply if new equipment is being installed to serve the addition. A common situation with additions is to use existing heating and/or cooling equipment and extend it to the addition. For larger additions, existing systems will likely not have adequate capacity and new systems may need to be installed. When existing systems are extended to meet the needs of additions, the *Standards* apply only to the new ductwork or piping needed to provide the extension (see Duct Sealing below). When a new central air conditioner is installed in conjunction with an addition that will serve the addition and the existing building, the new air conditioner is an alteration. Such new systems must meet the mandatory requirements and have either diagnostically tested refrigerant charge and airflow measurement or a field verified TXV or must have a minimum 12 SEER efficiency. This requirement applies regardless of the size of the addition. The Alternative to Package D can not be used to determine compliance if a new central air conditioner is installed in conjunction with an addition that will serve the addition and the existing building

Electric Heat

The Package D prescriptive requirements do not allow electric resistance space heating, however, if an existing house has electric resistance heat, this existing system may serve the new addition if it has adequate capacity. No new electric heaters may be installed.

Mandatory Measures

If a new space-conditioning system is installed to serve the addition alone, or the existing-plus-addition building, all mandatory measures shall apply including load calculations, certified equipment, duct insulation and installation, and a setback thermostat. No electric resistance space heating is allowed with prescriptive compliance. Only gas heating or heat pumps are permitted.

When existing heating and/or cooling equipment serves an addition, the existing equipment need not comply with the mandatory or compliance requirements of the *Standards*. However, the requirements for duct sealing apply (see Section 7.2.3, Duct Sealing).

Setback Thermostats

The prescriptive packages require a setback thermostat. With performance methods, the budget building has a setback thermostat and the proposed building suffers an energy penalty if it does not also have one. If a non-central space-conditioning system of one of the following types is installed and is modeled without a setback thermostat, then the mandatory measures do not require a setback thermostat.

- Gravity-gas wall heaters
- Gravity floor heaters
- Gravity room heaters
- Non-central electric heaters
- Room air conditioners
- Room air conditioner heat pumps

New Distribution Systems

If a new HVAC distribution system serves the addition and the existing building, the new air distribution system may be modeled in the existing-plus-addition case to receive energy credit. The system must be diagnostically tested by a HERS rater (see Chapter 4). Testing can be avoided with the performance method, but 22% leakage must be assumed and this is a significant energy penalty. The Alternative to Package D (see Table 3-2) may also be used, but this package requires more energy efficient space conditioning equipment and windows, depending on climate zone.

Additions or alternations with no new ducts or with non-ducted equipment do not require diagnostic testing or field verification, since there is nothing to test or verify. Table 5-4 and Table 5-5 show the system used in the standard design for such systems.

Equipment Sizing Methods

There are two options for sizing and installing heating, ventilation and air-conditioning (HVAC) equipment for additions. The first is to perform design heating and cooling load calculations for the addition by itself and to install separate HVAC equipment for the addition that does not connect to the existing HVAC system.

The second option is to calculate heating and cooling loads for the existing-plus-addition. The calculated size can be used to justify the use of existing equipment or to select new HVAC equipment. It is acceptable to use existing heating equipment to heat the existing-plus-addition, provided the existing equipment meets or exceeds the design heating load per *UBC* requirements (see Section 2.5).

Cooling load calculation requirements are specified in the *Standards* when cooling equipment is installed. If you are using an existing air conditioner to cool an addition, cooling load calculations for the existing-plus-addition are recommended but not required.

Example 7-5 – Existing Electric Resistance Heaters

Question

An existing house has an electric resistance furnace. Can this furnace be used to serve the needs of the addition?

Answer

Yes, as long as it has adequate capacity. However, no additional electric heaters may be installed in the addition.

Refrigerant Charge And Airflow Measurements / Thermostatic Expansion Valves

If a new split system air conditioner or heat pump is installed as part of a Package D addition, then the equipment must be diagnostically tested by the installer and diagnostically tested and field verified as having the correct refrigerant charge and airflow across the evaporator coils or having a thermostatic expansion valve installed." As an alternative, a thermostatic expansion valve may be installed and field verified by a HERS rater instead of the refrigerant charge and airflow measurement. The alternative to Package D can be used in lieu of the requirements for refrigerant charge and airflow testing or a TXV if the new split system central air conditioning serves only the addition (See Table 3-2). If the new split system central air conditioner serves both the addition and the existing building, the Alternative to Package D can be used for determining compliance, however, installation of a new air conditioner to serve both the existing house and the addition is considered an alteration, and would have to meet the requirements for diagnostically tested refrigerant charge and airflow measurement or install a field verified TXV. To avoid the diagnostic testing and field verification, a SEER 12 or greater would be required.

If existing equipment is extended to serve the addition, then these requirements do not apply.

Example 7-6 – Refrigerant Charge and Airflow or TXV in Additions

Question

Do the TXV or refrigerant charge and airflow measurement in §151 (f) need to be met for central split system air conditioners serving an addition?

Answer

If existing equipment is used to serve the addition, this requirement does not need to be met as specified by Exception 4 to §152(a).

If a new central split system is installed to serve the addition, it must either:

- meet the TXV or refrigerant charge and airflow measurement in order to comply with Package D; or
- meet the requirements of alternative to Package D (the building must also meet the window requirements and equipment efficiency requirements in the Alternative to Package D. However, installation of a new air conditioner to serve both the existing house and the addition is considered an alteration, and would have to meet the requirements for diagnostically tested refrigerant charge and airflow measurement or install a field verified TXV. To avoid the diagnostic testing and field verification, a SEER 12 or greater would be required); or

Duct Sealing

Prescriptive Package D requires that air distribution ducts be diagnostically tested so that leakage is 6% of fan airflow or less. The Alternative to Package D (see Table 3-2) does not require diagnostic testing of duct leakage, but instead requires more efficient windows and space conditioning equipment. Performance compliance requires diagnostic testing when duct sealing is chosen for compliance (in either the addition alone or in existing-plus-addition)."

There are two common situations for air distribution systems in residential additions. The first is when a separate air distribution system serves an addition. This is straightforward; the new system is tested by the installer and a HERS rater using the procedures in Appendix J of this *Manual*. To meet the prescriptive requirements, measured leakage in the new duct system must be less than or equal to 6% of the fan airflow.

The second situation is where an existing air distribution system is extended to serve the house addition. Typically new registers are installed and duct runs are added from an existing plenum box. The prescriptive requirements still apply in this case, but it is not possible to test just the new ducts. Instead, the entire duct system must be tested, both existing and new. The remainder of this section discusses this situation.

Determining the Target Percent Leakage

There are two ways to determine the target leakage for existing duct systems with new runs serving an addition. The easiest, but most stringent approach is to use the 6% leakage target, which is appropriate for new duct systems. While this goes beyond the minimum requirements, it will likely be cost effective and provide great benefit to the homeowner in terms of energy savings.

The second approach is to assume that the new duct system leaks at the 6% rate required by prescriptive Package D and that the existing duct system leaks at the default Duct Leakage rate from Table 7-6. The default leakage rate in the existing house is 28% of fan airflow (pre-1999), 22% of fan airflow (1999-2001) and 6% of fan airflow (2001 to present). The target leakage rate is then weighted according to the floor area of the addition and the existing house. For example, assume that the new addition represents 25% of the existing-plus-addition floor area. The total system would have to be tested to have a flow less than 22.5% as shown in the following calculations.

Maximum Leakage = $\text{Fraction}_{\text{Addition}}$(6% Leakage) + $\text{Fraction}_{\text{Existing}}$ (28% Leakage)

Maximum Leakage = 0.25 (6%) + 0.75(28%) = 1.5% + 21% = 22.5%

Target air leakage percents are pre-calculated in Table 7-4 for various floor area combinations for the existing house and the addition. This table is based on 28% leakage for the existing house, which is only appropriate for houses constructed prior to 1999.

Table 7-4 – Target Percent Leakage for Air Distribution Ducts Serving Existing-Plus-Addition Duct Systems

Total Floor Area of Existing House	Floor Area of Addition: 100	200	300	400	500	600	700	800	900	1000	1200	1400	1600	1800	2000
1000	26	24	22	21	20	19	18	18	17	17	16	15	14	13	13
1100	26	24	23	22	21	20	19	18	18	17	16	15	14	14	13
1200	26	24	23	22	21	20	19	19	18	18	17	16	15	14	14
1300	26	25	23	22	21	21	20	19	19	18	17	16	15	15	14
1400	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15
1500	26	25	24	23	22	21	21	20	19	19	18	17	16	16	15
1600	26	25	24	23	22	22	21	20	20	19	18	17	17	16	15
1700	26	25	24	23	23	22	21	20	20	19	18	18	17	16	16
1800	26	25	24	24	23	22	21	21	20	20	19	18	17	17	16
1900	26	25	25	24	23	22	22	21	20	20	19	18	17	17	16
2000	26	26	25	24	23	22	22	21	21	20	19	18	18	17	17
2100	27	26	25	24	23	23	22	21	21	20	20	19	18	17	17
2200	27	26	25	24	23	23	22	22	21	21	20	19	18	18	17
2300	27	26	25	24	24	23	22	22	21	21	20	19	18	18	17
2400	27	26	25	24	24	23	23	22	22	21	20	19	19	18	18
2500	27	26	25	24	24	23	23	22	22	21	20	20	19	18	18
2600	27	26	25	25	24	23	23	22	22	21	21	20	19	19	18
2700	27	26	25	25	24	24	23	22	22	22	21	20	19	19	18
2800	27	26	25	25	24	24	23	23	22	22	21	20	20	19	18
2900	27	26	25	25	24	24	23	23	22	22	21	20	20	19	19
3000	27	26	26	25	24	24	23	23	22	22	21	21	20	19	19
3100	27	26	26	25	24	24	23	23	23	22	21	21	20	19	19
3200	27	26	26	25	25	24	24	23	23	22	22	21	20	20	19

Note: These target percentages are based on the existing house being constructed before 1999, e.g. the default leakage is 28%. Values are rounded down to the nearest whole percentage.

Determining Fan Airflow

With either of the above methods, it is necessary to determine the fan airflow before the leakage can be calculated. Fan airflow can be determined using one of four methods described below:

1. Fan airflow can be based on the cooling capacity of the equipment. With this method the fan airflow is assumed to be 400 cfm/ton times the capacity of the equipment in tons. This is the most common and easiest method to determine fan flow.
2. Fan airflow can be based on the heating capacity of the equipment. In this case the fan airflow is assumed to be 21.7 cfm/(kBtu/h) times the capacity of the heating equipment in thousands of Btu/h. This method is typically used for heating only systems.
3. The fan airflow can be based on floor area. For climates 8 through 15, fan airflow can be assumed to be 0.7 cfm/ft² times the floor area served by the system. For climates 1 through 7 and 16, the fan airflow can be assumed to be 0.5 cfm/ft² times the floor area served. This is the default method used by the approved computer methods.
4. The fan airflow can be measured in the field (see Appendix J for measurement procedures).

Calculating Duct Leakage

Once the percent leakage and the fan airflow are determined using the methods discussed above, the duct leakage is calculated by multiplying the two values. For instance if the fan airflow is 1,200 cfm and the target percent leakage is 25%, then the target duct leakage is 1,200 cfm x 25% or 300 cfm. Since there is more than one method of determining the fan airflow and the percent leakage, the target duct leakage value can be the greater of the values determined.

Verifying Compliance

Once the target leakage is determined, the installer and a HERS rater must perform diagnostic testing to verify that the leakage is less than the target value. The procedures that the installer and HERS rater follow are documented in Appendix J of this *Manual*.

Alternatives to Diagnostic Testing

There are several alternatives to diagnostic testing of duct systems in additions. When the prescriptive method is used for the addition alone, the Alternative to Package D may be used (see Table 3-2). This alternative package requires windows with a lower U-factor and SHGC. The alternative package also requires air conditioning or heating equipment with a higher efficiency, but only for new equipment installed to serve the addition. See Refrigerant Charge And Airflow Measurements / Thermostatic Expansion Valves above for related requirements when replacing existing equipment. The Alternative to Package D may also be used when the existing-plus-addition house is treated entirely as new construction.

Example 7-7 – Duct Sealing in Additions – Extending a Duct from an Existing System

Question

When extending a duct to an addition from an existing system, what is required to meet the leakage requirements for that piece of duct using the prescriptive method? The existing house is 1,800 ft² and the addition is 400 ft². The existing system has a cooling capacity of 4 tons and a heating capacity of 75,000 Btu/h. The building is located in climate zone 12.

Answer

One option is to use the Alternative to Package D (see Table 3-2), which requires windows with a lower U-factor and SHGC, but eliminates the need for diagnostic testing. See Refrigerant Charge And Airflow Measurements / Thermostatic Expansion Valves above for requirements related to replacing equipment. If Package D is used, then it is necessary to test the entire duct system, which combines both the new and existing portions. It is not possible to test just a portion of the duct system. The leakage against which the system is tested can be determined by two methods: either the system can be tested against a criteria of 6% leakage or an area weighted average target leakage percentage can be calculated based on the floor area of the addition and the existing house. See a discussion of these methods in the text above. Based on the 1,800 ft² existing house and 400 ft² addition, the target leakage is 24% from Table 7-4.

The target percent leakage rates must be multiplied by the estimated fan airflow in order to determine the target duct leakage in cfm. The fan flow can be estimated from the cooling capacity (400 cfm/ton times 4 tons equals 1,600 cfm), from the heating capacity (21.6 cfm/(kBtu/h) times 75 kBtu/h equals 1,620 cfm) or from the floor area of the space (0.7 cfm/ft² times 2,200 ft² equals 1,540 cfm).

The largest of these values can be used to determine the target leakage rate in cfm. The largest value in this example is based on heating and is 1,620 cfm. 24% of this is 389 cfm, which is the target leakage rate against which the installer and HERS rater must test the duct system.

Question

An addition is 300 ft². Ductwork from the existing house will be extended to serve the addition. Is there a way to use the prescriptive standards for the addition alone and avoid having to test the duct leakage? The house is located in climate zone 10.

Answer

Yes. You may use the Alternative to Package D (see Table 3-2). For climate zone 10, this requires installing new windows in the addition with a U-factor of 0.40 or less and a

SHGC of 0.35 or less. If a new air conditioner were installed, it would have to have an SEER of 11.0 or greater to meet the Alternative to Package D requirements. However, installation of a new air conditioner to serve both the existing house and the addition is considered an alteration, and would have to meet the requirements for diagnostically tested refrigerant charge and airflow measurement or install a field verified TXV. To avoid the diagnostic testing and field verification, a SEER 12 or greater would be required. Other requirements of Package D apply to the addition, as applicable (see Table 3-1).

7.2.4 Water Heating

Addition Alone Compliance

When compliance is shown for the addition alone, water heating is considered separately and may not be traded off with space conditioning energy (heating and cooling). If the existing-plus-addition method is used or if the construction project is treated as entirely new construction, then water heater energy can be traded off.

With the addition alone method, an additional water heater may be added to the house, but it must have a storage capacity no larger than 50 gallons and a recirculating system is not permitted. If natural gas is provided to the building, the new water heater must be a natural gas water heater with an energy factor (EF) of 0.53 (the requirement of the minimum efficiency standards of §112). If the EF of the new water heater is less than 0.58, then an R-12 external wrap must be installed. An additional electric water heater may be added only if there is no gas service at the site; it too is limited to 50 gallons of storage capacity and must have an energy factor of 0.90 or better. If you want to add a water heater with a larger storage capacity than 50 gallons, then the energy factor must be improved or a more efficient water distribution system must be used. Table 7-5 shows water heating system types that are permitted in additions.

Table 7-5 – New Water Heaters Permitted in Additions – Addition Alone Compliance Method

A water heater with the following characteristics may be installed in an addition to a building with a *natural gas connection*, without credit/penalty in compliance calculations:			
Fuel/Type	Capacity	Efficiency	Distribution
Gas/Storage	50 gallon	≥ 0.525 EF	Standard
Gas/Storage	75 gallon	≥ 0.52 EF	PI
Gas/Storage	75 gallon	≥ 0.52 EF	POU
Gas/Storage	75 gallon	≥ 0.52 EF	HWR
Gas/Storage	75 gallon	≥ 0.52 EF	PP
Gas/Storage	75 gallon	≥ 0.52 EF	WSB
Gas/Instantaneous	N/A	≥ 0.62 EF	Standard
A water heater with the following characteristics may be installed in an addition to a building with *no natural gas connection*, without credit/penalty in compliance calculations:			
Fuel/Type	Capacity	Efficiency	Distribution
Electric/Storage	50 gallon	> 0.90 EF	Standard
Electric/Storage	50 gallon	> 0.86 EF	POU
Electric/Storage	50 gallon	> 0.86 EF	HWR
Electric/Storage	50 gallon	> 0.86 EF	WSB
Electric/Storage	50 gallon	> 0.86 EF	PI
Electric/Storage	50 gallon	> 0.86 EF	PP
Electric/Storage	50 gallon	> 0.86 EF	R/D & HWR
Electric/Storage	75 gallon	> 0.95 EF	Standard
Electric/Instantaneous	N/A	> 98% RE	Standard

Notes:	POU: Point of Use
EF = Energy Factor	PI: Pipe Insulation
RE = Recovery Efficiency	HWR: Hot Water Recovery System
Distribution Systems (see Sections **6.1** and **6.6**, for complete information on distribution system installation criteria):	PP: Parallel Piping WSB: Wood Stove Boiler
Standard: No pumps, R-4 insulation on first 5 feet of hot and cold water pipes	R/D & HWR: Recirculation system with a Demand control, combined with Hot Water Recovery

7.3 Performance Requirements for Additions

With the performance method, either for the addition alone or for the existing-plus-addition building, tradeoffs can be made with other building measures, as long as the source energy of the proposed building is less than or equal to the source energy of the budget building. There are some constraints on these trade-offs.

The budget building with the performance method is based on prescriptive Package D. Credit is offered for more energy efficient measures and penalty for less efficient measures. The only limitation is minimum mandatory measures: ceilings must have a weighted average equivalent to R-19 installed between wood framing, and framed walls must have a weighted average equivalent to R-13 installed between wood framing (except as noted above for existing walls insulated to R-11).

When using performance compliance where there is either no cooling or no new cooling system, modeling assumptions for this hypothetical cooling system should match the Package D requirements for refrigerant charge and airflow (e.g., Climate Zone 12, no cooling assumptions are 10 SEER with refrigerant charge and airflow). (See Section 7.2.3, Refrigerant Charge And Airflow Measurements / Thermostatic Expansion Valves)

Performance compliance requires diagnostic testing when duct sealing is chosen for compliance (in either the addition alone or in existing-plus-addition – see Section 7.2.3, Duct Sealing). If a separate air distribution system is installed for the addition, then this new system must be tested and sealed to have a leakage less than or equal to 6% of the fan airflow. If an existing air distribution system is extended to serve the addition, this too must be tested, but the testing target leakage depends on the size of the addition and other factors discussed in Section 7.2.3, Determining the Target Percent Leakage.

7.3.1 Mandatory Measures

As for prescriptive compliance the mandatory measures apply to all new construction, including additions (see Section 7.2.1).

If the performance method is used for compliance (either the addition alone or existing plus addition approaches), the mandatory requirement for R-13 wall insulation does not apply if walls in the existing building already are insulated with at least R-11 (see §152(a)).

7.3.2 Addition Alone Procedure

Compliance for the addition alone is determined as for a new building but accounting for the fact that an addition is attached to an existing building with which is shares walls, internal loads, systems and equipment. This procedure is described in Section 5.4. Installation of a new split system central air conditioner to serve both the existing house and the addition is considered an alteration, and for existing alone compliance would have to meet the requirements for diagnostically tested refrigerant charge and airflow measurement or install a field verified TXV. To avoid the diagnostic testing and field verification, a SEER 12 or greater would be required, or compliance will need to be met using the existing plus addition approach.

Example 7-8 – Refrigerant Charge and Airflow or TXV in Additions

Question

When using the performance approach for the addition alone, do the TXV or refrigerant charge and airflow measurement in §151 (f) need to be met for central split system air conditioners serving an addition?

Answer

If existing equipment is used to serve the addition, this requirement does not need to be met as specified by Exception 4 to §152(a). For performance compliance in climate zones that require a TXV or refrigerant charge and airflow measurement in Package D, a hypothetical 10 SEER split system with this credit would be modeled in both the standard and the proposed designs, resulting in neither credit nor penalty related to this feature.

If a new central split system is installed to serve the addition, it must either:

- meet the TXV or refrigerant charge and airflow measurement in order to comply with Package D; or
- to avoid the diagnostic testing and field verification, meet a SEER 12 or greater; or
- meet the criteria modeled for the proposed design in the performance approach.

7.3.3 Existing-Plus-Addition Procedure

The following steps are used to demonstrate compliance using the existing-plus-addition approach:

1. Collect and document information on the existing building before the remodel. This will generally require an audit or survey of the existing building. Data collected should include:
   - Geometric information about the house, including floor, ceiling, wall and fenestration areas, separated by orientation.
   - Insulation installed in floor, ceiling and wall cavities
   - Fenestration performance characteristics including U-factor, SHGC, and shading conditions (overhangs or sidefins)
   - HVAC equipment type and efficiency
   - Water-heating system type and efficiency
   - Duct leakage if tested
   - Other data as needed
2. Analyze the energy performance of the **existing building** using an approved computer method. The default assumptions from Table 7-6 are used in the analysis, unless actual field conditions are documented. The approved computer method automatically creates a budget building, which represents the existing building with Package D prescriptive requirements. Both the unmodified existing building and the budget building are simulated using consistent modeling rules, and an estimate of energy use is generated for each as described below:

   EU_e = The energy use in kBtu/y-ft² of the unmodified existing building. This energy use is calculated based on the default assumptions from Table 7-6, unless actual field conditions are documented.

   EB_e = The energy budget in kBtu/y-ft² of the existing building. This represents the energy use of the existing house if it were upgraded to meet all the requirements of the 2001 Energy Efficiency Standards.
3. Analyze the energy performance of the **existing-plus-addition building**, including any changes to the existing building. Data entered should account for all characteristics of the addition and the improved existing building, including windows and skylights that are removed from the existing house as part of the remodel. Data is entered about the existing-plus-addition building and the computer program automatically creates a budget building, representing the house, but in minimum compliance with Package D. The proposed building and the custom budget building are simulated and estimates of energy use are generated as described below: Audited/surveyed data on the characteristics of the existing building is entered.

   EU_{e+a} = The estimated energy use in kBtu/y-ft² of the existing-plus-addition house as it is proposed and shown on the plans and specifications. In this case, either the conditions used for determining EU_e, or the proposed improvements to the existing building are used.

   EB_{e+a} = The energy budget in kBtu/y-ft² of the custom budget version of the existing-plus-addition house.

   Note: If the energy budget for the existing-plus-addition is greater than its energy use, then the addition complies automatically and no additional calculations are required. This is equivalent to the new construction compliance approach
4. Calculate the ratio (F) by dividing the conditioned floor area (CFA) of the existing house (A_e) by the CFA of the existing-plus-addition house (A_{e+a}).

Equation 7-1

$F = (A_e) / (A_{e+a})$

Where:

A_e = Total conditioned floor *area* of the *existing* building, in square feet.

A_{e+a} = Total conditioned floor *area* of the remodeled *existing-plus-addition* building, in square feet.

5. Calculate the energy budget for the existing-plus-addition and compare this to the energy use of the existing-plus-addition house. The energy budget is the energy budget of the existing-plus-addition house (EB_{e+a}) plus additional energy representing improvement in the existing house. The additional energy is the difference between the energy use and energy budget of the existing house, but weighted by the fraction of the total conditioned floor area represented by the existing house. Compliance is achieved if the following expression is true.

Equation 7-2

$EU_{e+a} \leq EB_{e+a} + (F(EU_e - EB_e))$

Note: If (EU_e - EB_e) is less than zero (0), use zero in the calculation.

Example 7-9 – Existing-Plus-Addition Analysis Using an Approved Computer Method

Question

An addition of 590 ft^2 is being added to an existing 2,389 ft^2 single-family house. How do you demonstrate compliance using the existing-plus-addition method?

Answer

This process requires the following steps:

Collect information about the existing building.

Analyze the existing building before the addition. The energy budget of the existing building is calculated as 45.58 kBtu/y-ft², while the energy use of the existing building is 108.39 kBtu/y-ft².

Analyse the existing-plus-addition building. The energy budget of the existing-plus-addition is calculated as 42.37 kBtu/y-ft², while the energy use of the existing-plus-addition is 88.21 kBtu/y-ft².

Calculate the ratio of the existing building to the existing-plus-addition building:
F = 2,389/(2,389 + 590) = 0.802

Calculated energy budget for the existing-plus-addition building and compare to the proposed existing-plus-addition building.

$EB_{e+a} + (F)(EU_e - EB_e)$

= 42.37 + (0.802)(108.39 - 45.58)

= 42.37 + (0.802)(62.81)

= 92.74 kBtu/yr-ft^2

Since the energy use of the existing-plus-addition (88.21 kBtu/y-ft² is less than its adjusted energy budget (92.74 kBtu/y-ft²), the addition complies.

Example 7-10 – Refrigerant Charge and Airflow or TXV in Additions

Question

When using the existing plus addition performance approach, do the TXV or refrigerant charge and airflow measurement in §151 (f) need to be met for central split system air conditioners serving an addition?

Answer

If existing equipment is used to serve the addition, this requirement does not need to be met as specified by Exception 4 to §152(a). For performance compliance in climate zones that require a TXV or refrigerant charge and airflow measurement in Package D, a hypothetical 10 SEER split system with this credit would be modeled in both the standard and the proposed designs, resulting in neither credit nor penalty related to this feature.

If a new central split system is installed to serve the addition, it must meet the criteria modeled in the performance approach. However, installation of a new air conditioner to serve both the existing house and the addition is considered an alteration, and would have to meet the requirements for diagnostically tested refrigerant charge and airflow measurement or install a field verified TXV. To avoid the diagnostic testing and field verification, either a SEER 12 or greater would be required or the performance of other building features must be improved.

Question

When using the existing-plus-addition performance compliance method, can credit be gained by installing a TXV or doing refrigerant charge and airflow measurement on the existing central split system air conditioner in the existing house?

Answer

Yes, the same requirements for the TXV or refrigerant charge and airflow measurement for a new central split system air conditioner must be met, including HERS rater verification. The credit is offered through the performance method, which adjusts the efficiency of equipment, depending on whether or not the refrigerant charge and airflow have been diagnostically tested.

Example 7-11 – Duct Sealing in Additions – Compliance Credit for Sealing Existing Ducts

Question

When using the existing plus addition performance method, can compliance credit be gained by sealing the existing ducts?

Answer

Yes. The budget building is based on ducts with a leakage of 6% serving the addition (as required by Package D) and ducts serving the existing house having a leakage of 28% (default for pre-1999 construction) or 22% (default for 1999 to 2001 construction. If the entire duct system is designed and tested to have a leakage of 6% or less and is diagnostically verified by a HERS rater, then significant compliance credit is available. See the discussion of the performance approach in the text above.

Example 7-12 – Radiant Barriers in Additions

Question

Where do radiant barriers need to be installed when using the performance standards where no credit is taken for retrofitting a radiant barrier in the existing house?

Answer

The radiant barrier only needs to be installed on the underside of the roof assembly associated with the addition.

Question

When using the existing plus addition performance compliance method, can credit be gained by installing a radiant barrier in the existing house attic? If so, where does the radiant barrier need to be installed?

Answer

Yes, installing a radiant barrier in the existing building will result in a credit relative to the standard design for existing buildings permitted (or constructed) prior to June 1, 2001.

The radiant barrier must be installed over the entire attic/roof area including gable walls. If there are roof/ceiling assemblies where it is not possible to reach the underside of the roof, such as roof/ceiling assemblies using enclosed rafters which are not proposed to be exposed as part of the project, the radiant barrier cannot be properly installed and compliance credit is not possible.

7.3.4 Default Assumptions About the Existing Building

The existing-plus-addition compliance method requires that data be entered for two conditions, the existing house and the improved existing-plus-addition house. For the first case, use actual conditions where known. Where existing conditions cannot be determined, use default performance characteristics from Table 7-6. For the existing-plus-addition house, credit may be taken for any proposed improvements to the existing house (that will be constructed under the same permit as the addition).

Residential construction and additions built in California from 1978 to the present were required to comply with the *Standards*. Select the values from Table 7-6 that corresponds to the year that the building was constructed or the date of the most recent addition, which ever is later. Existing non-central systems are always assumed to have a non-setback thermostat. Existing central systems are always assumed to have a setback thermostat. Floor and fenestration areas must always be accurately calculated in both the existing and the existing-plus-addition analyses.

Table 7-6 – Default Assumptions for Existing Buildings

Feature		Before 1978	1978 to 1983	1984 to 1991	1992 to 1998	1999 to 2001	2001 to Present
		Construction Date or Date of Last Remodel					
Roof U-factor Notes: (1)		0.047	0.047	0.047	0.047	0.047	0.047
Wall U-factor Notes: (1)		0.385	0.098	0.098	0.088	0.088	0.088
Raised Floor U-factor Notes: (1)	Crawlspace	0.097	0.097	0.097	0.037	0.037	0.037
	No Crawlspace	0.238	0.238	0.238	0.049	0.049	0.049
Slab Edge F-factor (2)		0.76	0.76	0.76	0.76	0.76	0.76
Duct R-value		R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2
Building Leakage (SLA)		4.9	4.9	4.9	4.9	4.9	4.9
Duct Leakage		28%	28%	28%	28%	22%	6%
Fenestration U-factor		Use Table 1-D, Title 24, Part 6, §116 for all vintages					
Fenestration SHGC		Use Table 1-E, Title 24, Part 6, §116 for all vintages					
Shading Device		Use current value for installed device					
Gas Furnace (Central), AFUE		0.75	0.78	0.78	0.78	0.78	0.78
Gas Heaters (Room), AFUE		0.65	0.65	0.65	0.65	0.65	0.65
Heat Pump, HSPF		5.6	5.6	6.6	6.6	6.8	6.8
Electric Resistance, HSPF		3.41	3.41	3.41	3.41	3.41	3.41
Space Cooling Efficiency SEER		8.0	8.0	8.9	9.7	9.7	9.7
Charge and Airflow Test or TXV		No	No	No	No	No	Yes
Water Heater	Energy Factor	0.53	0.53	0.53	0.53	0.58	0.58
	Rated Input, MBtu/h	28.0	28.0	28.0	28.0	28.0	28.0

Note that existing non-central systems are always assumed to have a non-setback thermostat. Existing central systems are always assumed to have a setback thermostat.

AFUE = Annual Fuel Utilization Efficiency

HSPF = Heating Seasonal Performance Factor

SEER = Seasonal Energy Efficiency Ratio

MBtu/hr = 1,000,000 Btu/hr

This table is based on Table 3.7 of the Residential ACM Approval Manual.

Notes:

(1) See Appendix I for equivalent assemblies and R-values.

(2) Also called F2-factor.

Note: The same values should be modeled for the existing house in both the existing and the existing-plus-addition analyses unless specific improvements, including those previously installed, are documented.

7.3.5 Water Heating Performance Compliance

Compliance credit for improved water heating systems can be gained through the performance method for existing-plus-addition and the new construction methods. For the existing house computer run, the efficiency and other characteristics of the water heater in the existing house is prescribed in Table 7-6. For the existing-plus-addition computer run, the proposed water heating system is modeled.

If an existing water heater is being replaced, use Table 7-6 to define the properties of the existing water heater and distribution system in the existing building run. Model the water heater that replaces the existing water heater, including any water heating distribution system changes, in the existing-plus-addition computer run.

If a water heater is being added, increasing the total number of water heaters in the building, model the existing (pre-construction) water heater and the existing distribution system in the existing house computer run. When modeling the existing-plus-addition computer run, include any changes to the water heating distribution system and all of the water heaters that will be a part of the building's water heating system when the construction is finished.

7.4 Documentation for Additions

All Additions

For additions, the documentation needs are greater than for new construction since compliance credit is available for improvements to the existing building. The compliance needs vary, depending on the compliance approach and method. In all cases, however, it is necessary to complete the following compliance forms:

1. Certificate of Compliance (CF-1R) (see Chapter 1), and
2. Mandatory Measures Checklist (MF-1R) (see Chapter 2).

Note: When using the existing-plus-addition computer compliance method, upon compliance, the CF-1R may need to be filled out by hand.

Performance Methods

When the performance method is used for the addition alone, the existing-plus-addition building, or the entire building (new construction), then the CF-2R Computer Method form will be automatically generated by the certified computer program, in addition to the CF-1R and the MF-1R.

Other Documentation

Other compliance forms may also be needed as described below:

Form 3R Proposed Construction Assembly. Complete this form for special wall, roof or floor constructions used in the addition.

Form S Solar Heat Gain Coefficient (SHGC) Worksheet. Use this form to document compliance with the SHGC criteria.

CF-4R Certificate of Field Verification and Diagnostic Testing. The HERS rater completes this form when testing or field verification is required. For instance, if compliance credit is taken for duct sealing, field verification and diagnostic testing is required.

CF-6R Installation Certificate. Complete this form to document the installation of equipment.

IC-1 Insulation Certificate. Submit this form to document that insulation is properly installed.

Make note of any construction requirements on the plans and Certificate of Compliance (CF-1R), particularly improvements to the existing building necessary to achieve compliance with the *Standards*.

For detailed construction guidelines and documentation requirements for the builder, see Chapters 2 and 3.

As applicable, an Installation Certificate (CF-6R) for equipment and fenestration products must be completed and signed, as well as an Insulation Certificate (IC-1). Construction must be equal or better than information on the Certificate of Compliance (CF-1R).

The inspector should make note of any improvements required to achieve compliance, as indicated on the CF-1R. The plan checker should have either verified proof of past energy efficiency improvements, or have indicated on the CF-1R under "special features" any improvements that must be inspected. Proposed construction that is needed to achieve compliance will be indicated on the CF-1R.

For detailed inspection guidelines and documentation requirements, see Chapters 2 and 3.

Before making a visual inspection, check the Certificate of Compliance (CF-1R) and compare it to the Installation Certificate (CF-6R) for equipment and fenestration products, and to the Insulation Certificate (IC-1).

Check for features that require field verification and diagnostic testing, e.g. - reductions in building envelope leakage, more energy efficient duct location; duct sealing. Verify a CF-4R has been provided by a HERS rater for these features.

7.5 Alterations

§152

(b) ***Alterations.*** *Alterations to existing residential buildings or alterations in conjunction with a change in building occupancy to a low-rise residential occupancy shall meet either Item 1 or 2 below.*

1. *Prescriptive Approach. The altered component and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110 through 118 and 150; and*

   A. *Alterations that add fenestration area to a building shall be limited to a maximum 0.75 U-factor and the Solar Heat Gain Coefficient for new fenestration products as specified in Alternative Component Package D (Tables 1-Z1 through 1Z16).*

   B. *New space conditioning systems or components shall:*

      i *meet the requirements of Section 150(h) and (i) and Section 151 (f) 7.; and*

      ii *be limited to natural gas, liquefied petroleum gas, or the existing fuel type unless it can be demonstrated that the source energy use of the new system is more efficient than the existing system.*

   C. *New service water heating systems or components shall:*

      (i) *meet the requirements of Sections 150; and*

      (ii) *be limited to natural gas, liquefied petroleum gas, or the existing fuel type unless it can be demonstrated that the source energy use of the new system is more efficient than the existing system.*

2. *Performance Approach*

   A. *The altered components shall meet the applicable requirements of Sections 110 through 118 and 150; and*

   B. *Either:*

      i. *The permitted space alone, which shall be a minimum of the square footage of the room in which the alteration is made, shall comply with Section 151; or*

      ii. *The energy efficiency of the existing building shall be improved so that the building meets the energy budget in Section 151 that would apply if the* *existing building was unchanged and the permitted space alone complied with Item i. The permitted space shall be a minimum of the square footage of the room in which the alteration is made.*

EXCEPTION to Section 152 (b) 1 A: Any dual-glazed greenhouse window and dual-glazed skylight installed as part of the alteration complies with the U-factor requirements applicable to the prescriptive alterations.

NOTE: Fenestration products repaired or replaced, not as part of an alteration, need not comply with the U-factor and Solar Heat Gain Coefficient requirements applicable to alterations.

EXCEPTION to 152(b)2.B.: When the existing fuel type is electric, the existing or replacement equipment for heating, cooling and/or domestic water heating of the proposed building shall be assumed to be the same fuel type as the standard building.

…

(d) Any addition or alteration may comply with the requirements of Title 24, Part 6 by meeting the requirements for new buildings for the building as a whole.

7.5.1 Introduction

Alterations are changes to a building's envelope, space-conditioning system, water-heating system or lighting system, which are not additions. An alteration does not increase both conditioned volume and floor area. Examples include:

- Adding a new skylight (or window) to an existing building. If the skylight has a light well that cuts through an existing attic, the alteration adds conditioned volume but is not an addition because it does not add conditioned floor area.
- Adding a new greenhouse window to an existing building. This is an alteration rather than an addition because it adds conditioned volume to the building but not conditioned floor area.
- Adding a loft within the existing conditioned volume of a residence. This is an alteration rather than an addition because it adds conditioned floor area but not conditioned volume.

Prescriptive

Prescriptive compliance requires meeting mandatory measures on new systems or components being altered. New windows being added must meet a maximum U-factor of 0.75 (except dual-glazed skylights and dual-glazed greenhouse windows) and the maximum SHGC of Package D. Changing fuel types on equipment replacements is restricted.

Performance

Performance compliance requires meeting mandatory measures on new systems or components being altered. There is no limit on the U-factor of windows, and there is no restriction on changing fuel types, as long as the energy budget can be met.

7.5.2 Prescriptive Requirements

Alterations are remodels or replacements that do not increase a building's conditioned volume and conditioned floor area. Alterations may include changes to the building envelope, space-conditioning system, water-heating system and/or lighting system. In any alteration:

- All mandatory requirements apply to the component being changed.
- Any new fenestration products must have a U-factor equal to or less than 0.75 and meet the Package D SHGC requirements.

- Equipment replacements that involve a change in fuel type are restricted (see below).

Mandatory Measures

Any building or equipment alteration must comply with the relevant mandatory measures contained in §111 - §118, and §150 of the *Standards* (see Chapter 2 for a full discussion). The application of mandatory measures to alterations is discussed below.

Fenestration Requirements

Any added (not replaced) window, skylight, glass door or other fenestration installed must have a rated U-factor of 0.75 *or less* and meet the Package D SHGC criteria (see Section 2.3 and Section 3.3.3 on Fenestration). For the purposes of compliance for alterations, dual-glazed greenhouse windows and dual-glazed skylights may be assumed to meet the U-factor requirement (see Example 7-16).

Fenestration products that are replaced or repaired are not required to meet a maximum U-factor level or the SHGC criteria (see Examples 7-14 and 7-15).

Documentation

Compliance for a prescriptive alteration is documented on a:

- Certificate of Compliance (CF-1R) (see Chapter 1) and
- Mandatory Measures Checklist (MF-1R) (see Chapter 2).

Example 7-13 – Moving Existing Windows

Question

If I am doing an alteration, can I move an existing window to another location? Does it need to meet a 0.75 U-factor?

Answer

Once you move the window to a location where a window did not previously exist, it must meet the 0.75 U-factor requirements and the Package D SHGC criteria, because it is added fenestration rather than a window replacement or repair.

Example 7-14 – Alteration with New Windows

Question

An existing building has all single-pane, windows. All of the windows will be replaced, and one wall will be altered to have French doors in place of an existing window. What requirements apply?

Answer

The 0.75 U-factor and Package D SHGC requirements apply only to the new French doors, since these are considered new fenestration. There are no U-factor or SHGC requirements for the remainder of the windows being replaced. All of the installed fenestration must meet applicable mandatory measures described in Section 2.3.

Example 7-15 – Replacing windows

Question

An existing building has all single-pane, metal frame windows. A proposed remodel will replace all the windows; no other work is being done as part of the remodel. What applies?

Answer

Since there is no added fenestration, the 0.75 U-factor requirement or the SHGC requirement does not apply. However, the installed fenestration must meet applicable mandatory measures listed in Chapter 2.

Example 7-16 – Adding a greenhouse window to an existing building

Question

An existing building has all single-pane, wood frame windows. Two double-pane, metal frame greenhouse windows will be added as part of a remodel. How should the greenhouse windows be treated?

Answer

Since greenhouse windows (and some skylights) add conditioned volume, but do not add conditioned floor area, this remodel is considered an alteration rather than an addition. For the purposes of alterations, any dual-glazed greenhouse windows or skylights installed as part of an alteration may be treated as though they comply with the U-factor requirements applicable to prescriptive alterations. However, the Package D SHGC requirement applies to these windows. All applicable mandatory measures must be met.

New Space Conditioning Equipment

New heating and/or air conditioning systems installed in existing buildings are considered alterations. The appliance standards regulate the efficiency of most new residential heating and air conditioning equipment at the point of sale. However, the mandatory requirements for low-rise residential buildings also apply. In particular, §150 (h) requires that systems be appropriately sized and §150 (i) requires that the new systems have setback thermostats (see Section 2.5.3). The prescriptive requirements of §151 (f) 7 specify that new split system air conditioners or heat pumps installed in alterations must either be verified to have a thermostatic expansion valves (TXV) or be diagnostically tested to verify the correct refrigerant charge and airflow. As an alternative to the requirements for field verification and diagnostic testing for refrigerant charge and airflow measurement or a TXV, an air conditioner or heat pump with an SEER of 12 or greater may be installed. The Package D requirement for diagnostic testing of ducts does not apply to alterations.

Example 7-17 – Alteration of Existing Duct System

Question

As part of an upgrade in an existing house, one of the ducts is being replaced because of deterioration of the insulation and jacket. What requirements apply to the replacement duct.

Answer

This is an alteration since no new conditioned space is being added. The mandatory measures for ducts apply, but not the Package D requirement for diagnostic testing of the duct system. See Sections 2.5.6 and 2.5.7 for a summary of the mandatory measures for ducts.

Example 7-18 – New Air Handler and Plenum Platform

Question

An up-flow air-handling unit with a furnace and air conditioning coils is located on a platform in the garage of an existing house. The platform is used as a return air plenum. The air-handling unit is being replaced and the platform is being repositioned to the corner of the garage (three feet away from the current location). What requirements apply to this alteration?

Answer

The mandatory requirements apply to this alteration. In particular §150 (m) prohibits raised platforms or building cavities from being used to convey conditioned air (including return air and supply air). When the platform is relocated, it is being altered and the mandatory requirement applies. A sheet metal or other suitable duct must be installed to carry the return air to the replaced air-handler. This requirement would not apply if the platform were not being altered.

Fuel Switching

For prescriptive compliance, new electric resistance heating systems and electric water heating are prohibited in alterations unless the system being replaced is an electric resistance heating system or electric water heater. If the existing system is gas, propane or LPG, then new electric systems are not permitted. However, changing from a gas, propane or LPG space heating system to an electric heat pump is allowed as long as the heat pump efficiency is at least a 6.6 HSPF for package systems and a 6.8 HSPF for split systems.

Existing Heating System Fuel Source	***Acceptable Replacement Heating System Fuel Source(s)***
Electric	Electric, natural gas, or equipment with efficiency equal or better than existing system*
Natural gas	Natural gas, or equipment with efficiency equal or better than existing system*
LPG	Liquefied petroleum gas, natural gas, or equipment/ system with efficiency equal or better than existing system*

* Proof that equipment has an efficiency that is equal to or better than the existing system can be demonstrated by an approved compliance program or other approved alternative calculation method (Chapter 5) to compare the energy use of the existing system to the proposed system.

Example 7-19 – Replacing HVAC System

Question

If I am going to replace the heating system(s) in an existing residential building, what requirements of the *Standards* apply? Can I change fuel type (from electric to gas)?

Answer

Replacing the heating system is an alteration.The following mandatory requirements apply (see chapter 2):

- Certification of the equipment (not applicable to electric resistance heating equipment) (§111).
- Duct construction and insulation, if new ducts are being installed (§150(m)). The Package D requirement for diagnostic testing of the duct system does not apply.
- Setback thermostat requirements apply if the thermostat is replaced, unless the equipment is a gravity gas wall heater, gravity floor or room heater, non-central electric heater, room air-conditioners, or room air conditioner heat pump (§150(l)). (Existing-plus-alteration compliance is not needed for alterations).
- Sizing calculations (§150(h)).
- Changing fuel types is restricted as described under Fuel Switching above.

7.5.3 Water Heating

Alteration Compliance

As an alteration, an additional water heater may be added to the house. If natural gas is provided to the building, the new water heater must be a natural gas water heater with an energy factor (EF) of 0.53 (the requirement of the minimum efficiency standards of §112). If the EF of the new water heater is less than 0.58, then an R-12 external wrap must be installed. An additional electric water heater may be added only if there is no gas service at the site and it must have an energy factor of 0.90 or better. There is no size limit on an additional water heater.

If an existing water heater is being replaced, only the mandatory measures apply. This is true even if the replacement water heater has a greater capacity than the old one. The mandatory measures include: certification, pipe insulation near the water heater, and tank insulation (see Section 2.6).

Example 7-20 – Replacing Water Heaters

Question

What are the prescriptive compliance requirements for replacing water heaters that are not part of an addition? What if the replacement unit is larger? Can I change fuel types?

Answer

Replacement water heaters (which can be larger) must be certified and, if new pipes are installed, the new pipes must have the insulation required by §150(j). If the replacement is a gas storage water heater with an energy factor less than 0.58 then an R-12 blanket must be installed on the water heater.

Changing fuel types is restricted as described under Fuel Switching above. For prescriptive compliance, an electric resistance water heater may only be used if it is replacing an existing electric resistance water heater.

7.5.4 Performance Requirements

Any alteration may be analyzed using the performance method. The alteration may be considered alone or tradeoffs may be made with the existing building. These performance approaches may be appropriate for projects where it is not feasible for new fenestration products to achieve a 0.75 or lower U-factor, or where a change in space-conditioning or water heating fuel type is desired.

Alteration Alone

With the alteration-alone method, The compliance requirements are the same as showing compliance for a new building, except that the compliance is being shown for a smaller area of the building. Refer to the program compliance supplement for further modeling information for alterations. See also Chapter 5.

Existing-Plus-Alteration

The most flexible method for showing compliance for an alteration is to consider the existing building along with the alteration. The compliance requirements are the same as showing compliance for an existing-plus-addition, except that the compliance may be shown for a smaller area of the building (at least the room where the alteration is occurring must be included in the compliance). By comparing building energy consumption before and after the remodel, credit may be taken for improvements to the energy efficiency features in the existing building.

Example 7-21 – Modeling Existing-plus-Alteration

Question

One of the performance (computer) options for showing compliance for alterations is to show that the building meets the energy budget that would apply if the permitted space complied and the remainder of the building was unchanged. Can you explain what this means and the process for showing compliance?

Answer

This process involves four steps and three separate computer runs:

1. Model the building or a part of the building before any alterations to determine the energy use (proposed design) of the existing building.
2. Model the altered space to determine the energy budget (standard design) of the alteration alone.
3. Calculate the energy budget for the existing-plus-alteration as:

$$Energy\ Use\ Goal = \frac{A_e \times PD_e + A_a \times SD_a}{A_e + A_a}$$

Where:

A_e = Area of the existing building less area of the alteration (from 1.)

PD_e = Proposed design of the existing building before the proposed alteration (from 1.)

A_a = Area of the proposed alteration (from 2.)

SD_a = Standard design for the proposed alteration (from 2.)

4. Model the building, including the proposed alteration, along with any improvements to the existing building. If the proposed design is less than or equal to the energy use goal (from 3.), the alteration complies.

For example, 250 ft² of an existing 1,500 ft² building is being altered. In step 1, computer modeling shows that the existing building uses 25.4 kBtu/ft². In step 2, the proposed alteration's energy budget is 14.2 kBtu/ft².

Calculate the energy use goal as:

$$\text{Energy Use Goal} = \frac{1.250 \times 25.4 + 250 \times 14.2}{1{,}500} = 23.5$$

The above answer explains the concept of this approach. You should consult the program user manual for complete instructions, as some of the steps may be automated.

Trade-Offs

There is no maximum U-factor requirement for window replacements with the performance approach, but the budget building has all the features of prescriptive Package D (including the fenestration U-factor) and the proposed design must be shown to have equal or less source energy.

DocumentationCompliance for a performance alteration alone is documented on a:

1. Certificate of Compliance (CF-1R),
2. Mandatory Measures Checklist (MF-1R), and
3. Computer Summary (C-2R).

Note: There is no special allowance for greenhouse windows and skylights with the performance compliance approach for alterations, as there is for prescriptive alterations.

Mandatory Measures

All mandatory measures apply to any alterations. For example, if a new space-heating system is being installed, the equipment must be certified, sizing calculations are required, ducted systems must meet insulation and installation requirements, and a setback thermostat is required except for specific non-central system types. All mandatory measures are explained in Chapter 2.

7.5.5 Documentation Requirements

Make note of any construction requirements on the plans and Certificate of Compliance (CF-1R).

For detailed construction guidelines and documentation requirements for the builder, see Chapters 2 and 3.

As applicable, an Installation Certificate (CF-6R) for equipment and fenestration products must be completed and signed, as well as an Insulation Certificate (IC-1). Construction must be equal or better than information on the Certificate of Compliance (CF-1R).

The inspector should make note of any improvements required to achieve compliance, as indicated on the CF-1R. The plan checker should have either verified proof of past energy efficiency improvements, or have indicated on the CF-1R under “special features” any improvements that must be inspected. Proposed construction that is needed to achieve compliance will be indicated on the CF-1R.

For detailed inspection guidelines and documentation requirements, see Chapters 2 and 3.

Before making a visual inspection, check the Certificate of Compliance (CF-1R) and compare it to the Installation Certificate (CF-6R) for equipment and fenestration products, and the Insulation Certificate (IC-1) if there are any building envelope alterations.

Check for features that require HERS rater field verification and diagnostic testing, i.e., refrigerant charge and airflow measurement or TXVs on new air conditioners.

7.6 Repairs

Definitions
§101(b)

REPAIR is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. Note: Repairs to low-rise residential buildings are not within the scope of these standards.

A repair is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. In this case “part of a building” means a component, system or equipment, for which there are requirements in the Standards. In simple terms when such a component, system or equipment of an existing building breaks or is malfunctioning, and a maintenance person fixes it so it works properly again, that is a repair. If instead of fixing the break or malfunction, the component, system or equipment is replaced with a new or different one, that is an alteration not a repair. Repairs to low-rise residential buildings are not within the scope of these *Standards*. However, alterations must meet the applicable requirements of the Standards (see Section 7.5).

Some examples of repairs are 1) replacing a broken pane of glass but not replacing the entire window; 2) replacing a failed compressor in an air conditioner but not replacing the entire air conditioner; 3) replacing a failed fan motor or gas valve in a furnace but not replacing the entire furnace, 4) replacing a heating element in a water heater but not replacing the entire water heater. Some examples of alterations would be 1) installation of a new central air conditioning and heating system, 2) replacement of an air conditioner or the exterior unit or indoor coil of a split system air conditioner, 3) replacement of a furnace or water heater.

Example 7-22 – Buildings Damaged by Natural Disasters

Question

The *Standards* do not specify whether buildings damaged by natural disasters can be reconstructed to their original energy performance specifications. What requirements apply under these circumstances?

Answer

Buildings destroyed or damaged by natural disasters must comply with the energy code requirements in effect when the builder or owner applies for a permit to rebuild for those portions of the building that are being rebuilt.

8 Special Compliance Topics

This chapter discusses special topics as they apply to the various compliance paths for the *Energy Efficiency Standards* (*Standards*). For a discussion of other special topics not covered in this chapter, see Appendix G (*Glossary*). The special topics addressed in this chapter include:

- Multi-Family Buildings**.** Compliance of the building as a whole or unit-by-unit.
- Mixed Occupancy Buildings**.** Compliance of the dominant occupancy alone or each occupancy separately, and how mandatory measures apply.
- Subdivisions And Master Plans**.** Multiple orientations of the same plan.
- Fenestration Products (Glazing). An explanation of glazing terminology and the thermal performance rating system for all fenestration products.
- Wood Space Heating**.** A description of compliance for wood heat and installation criteria.
- Controlled Ventilation Crawl Space (CVC)**.** An explanation of the procedure for analyzing the energy use, as well as a listing of installation requirements, for CVC.
- Zonal Control. A description of the procedure for analyzing the energy use of zonally controlled space conditioning, as well as eligibility and installation criteria.
- Hydronic/Combined Hydronic Space Heating. An overview of hydronic space-heating systems and compliance calculations.
- Evaporative Cooling. A description of the energy credit for evaporative cooling, as well as eligibility and installation criteria.
- Geothermal (Ground Source) Heat Pump**.** A description of this type of space conditioning equipment along with efficiency information needed for complying with the *Standards*.
- Log Homes**.** An overview of the unique aspects of log homes, and how their special features can be accounted for in demonstrating compliance.
- Straw Bale Construction. An overview of the unique aspects of straw bale construction, and how its special features can be accounted for in demonstrating compliance.
- Radiant Barriers. A description of the energy credit for radiant barriers, as well as a listing of eligibility and installation requirements.

8.1 Multi-Family Buildings

In a multi-family building, one dwelling unit shares a common wall and/or floor or ceiling with at least one other dwelling unit. The information contained in this *Residential Manual* applies only to low-rise multi-family buildings. See definitions below.

§101(b)

The following are definitions from §101 of the standard.

HABITABLE STORY is a story that contains space in which humans may work or live in reasonable comfort, and that has at least 50 percent of its volume above grade.

HIGH-RISE RESIDENTIAL BUILDING is a building, other than a hotel/motel, of occupancy group R-1 with four or more habitable stories.

LOW-RISE RESIDENTIAL BUILDING is a building, other than a hotel/motel, that is of occupancy group R-1 and is three stories or less, or that is of occupancy group R-3.

Multi-family apartment buildings with four or more habitable stories (and hotels or motels of any number of stories) are covered by the nonresidential standards. These are explained in the Nonresidential Manual, which is available from www.energy.ca.gov/title24. Multi-family buildings with one to three habitable stories are considered low-rise residential buildings and are discussed in this *Manual*. See Table 1-4 for a listing of buildings within the scope of the low-rise residential standards, including occupancy group R-2 and congregate residences.

Since there are different standards that apply to low-rise multi-family and high-rise multi-family buildings, it is important to first verify the number of habitable stories in the building. Only those habitable stories that have more than half of their volume above grade should be counted in determining the number of habitable stories, and all conditioned space should be accounted for.

Compliance for a low-rise multi-family building may be demonstrated either for the building as a whole or on a unit-by-unit basis. Walls between dwelling units are considered to have no heat transfer, and may be ignored in performance calculations.

Whole Building Compliance

The simplest approach to compliance for a multi-family building is to treat the building as a whole, using any of the compliance paths described in earlier chapters. In practice, this process is similar to analyzing a single-family residence except for some differences in water-heating budgets explained in Chapter 6. Some of the modeling assumptions used in performance calculations are also different, in particular internal gains from lights, people, appliances, etc.

Compliance Unit-By-Unit

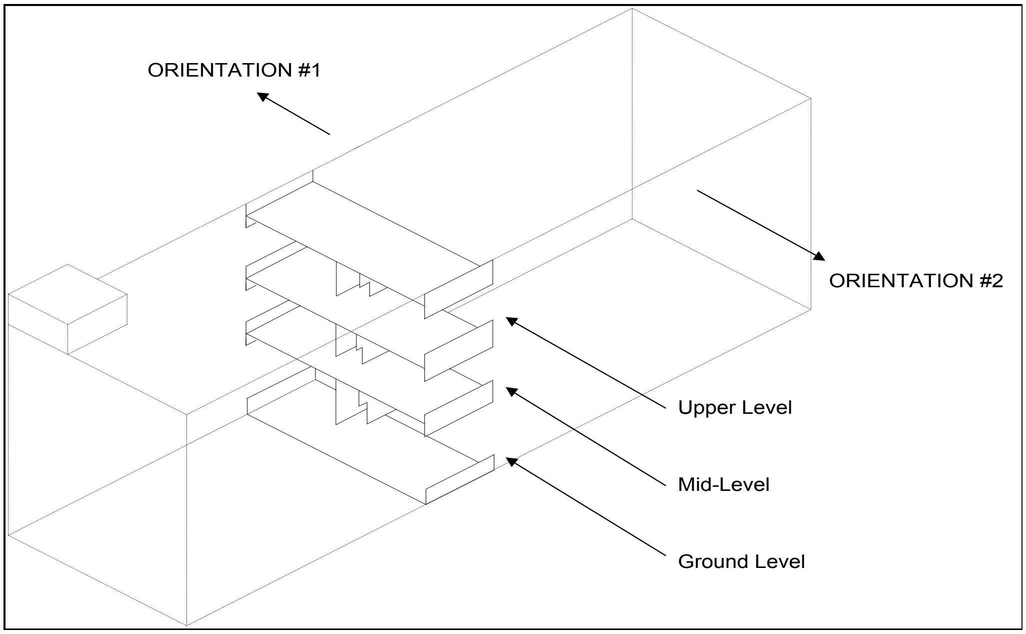
The other compliance approach for multi-family buildings is to demonstrate that each dwelling unit complies separately. Each unique unit in the building determined by orientation and floor level must be separately modeled using an approved computer program. In this approach, surfaces, which separate dwelling units, may be ignored as they are assumed to have no heat loss or heat gain associated with them.

Different orientations and locations of each unit type within the building must be considered separately. That is, a one-bedroom apartment on the ground floor of a three-story building is different from the same plan on a middle floor or the top floor, even if all apartments have the same orientation and are otherwise identical. With this approach every unit of the building must comply with the standard, so this approach is more stringent than modeling the building as a whole (see Figure 8-1).

Other options for showing unit-by-unit compliance are similar to those for subdivisions and are explained in Section 8.3 of this chapter.

Figure 8-1 – Multi-Family Building Compliance Option

Demonstrate Compliance for Each Generic Unit Type in Each of its Characteristic Locations



Example 8-1 – Multi-Family Building Compliance, Examples

Question

When preparing compliance calculations for a three-story apartment complex, I have the option of showing compliance for each dwelling unit or for the entire building. If I use the individual dwelling unit approach, do I need to provide calculations for every dwelling unit?

Answer

Each dwelling unit must comply with the *Standards* when using this approach. When dwelling units have identical conditions the calculations can be combined. This means you will show separate compliance for all unique conditions, such as:

· Front facing North

· Front facing West

· Front/side walls facing East and North

· Front/side walls facing East and South

· Exterior roof, no exterior floor

· Exterior floor, no exterior roof

Surfaces separating two conditioned spaces (such as common walls) have little heat transfer and can be disregarded in the compliance calculations. Alternatively, you can model the entire building.

Example 8-2 – Multi-Family Building Duct Testing

Question

How does the sampling procedure for diagnostic testing for air distribution ducts apply to multi family buildings?

Answer

The simplest approach is to not do sampling. In this case, the duct system associated with every HVAC unit in every multi-family building would be tested.

If the builder chooses to do sampling, then the sampling is done on a whole building basis (consistent with how compliance documentation is done). Under sampling, first a determination needs to be made of how many different types of buildings there are in the development. If every building is different, then sampling doesn't apply and every duct system associated with every HVAC unit in every building in the development has to be tested.

If some buildings are identical, then sampling can be done. For the buildings that are identical, the first of each "model" must be tested. In this building, the duct system associated with every HVAC unit in this building must be tested. After that a sample of the remaining buildings must be tested, according to the procedure in Section 4.4.4. In a building that is to be tested in sampling, the duct system associated with every HVAC unit in that building must be tested. No duct systems have to be tested in buildings that are not selected for sampling. In other words this is a sampling of whole buildings not a sampling of dwelling units within buildings. (Hypothetically, sampling of dwelling units could be done if compliance is shown separately for every dwelling unit in a building.)

Testing must be done on every duct system in a building regardless of whether it appears that the HVAC and duct system are in conditioned space or not. This is akin to a single family residence with one HVAC unit serving upstairs with ducts in the attic and another serving downstairs with ducts between floors. For this single-family counterpart case, both duct systems must be tested to get the duct sealing compliance credit.

The duct pressurization test has no way to determine if leakage is to outside or to inside. So, through this T-24 test there is no way to determine if the "plenum" which contains the ducts communicates to outside or not.

Also, "inside" and "outside" for leakage purposes is not defined by the locations of walls or the number of stories. The boundary between inside and outside for leakage purposes, is defined by the air boundary, typically drywall, between inside and outside. Spaces between floors and spaces in walls (including interior walls) are often "outside" from a air leakage perspective because they are not sealed effectively to form an air barrier and communicate to the outside.

Duct insulation is not required for ducts in conditioned space because there is an expectation that there will be reduced conduction losses for these ducts. But to get full credit for ducts in conditioned space, duct leakage must be tested and meet the requirements for duct sealing. In a multi-family building in order for compliance credit to be taken for ducts in conditioned space, all of the duct systems in the building must be in conditioned space unless compliance is documented for each dwelling unit separately.

To meet the mandatory requirements all HVAC units must have ducts made of UL 181 approved materials (i.e., cased coils). Coils enclosed by sheetrock do not meet the mandatory requirements.

8.2 Mixed Occupancy Buildings

§100(e))

When a building is designed and constructed for more than one type of occupancy, the space for each occupancy shall meet the provisions of Title 24, Part 6 applicable to that occupancy.

EXCEPTION to Section 100(e): If one occupancy constitutes at least 90 percent of the conditioned floor area of the building, the entire building may comply with the provisions of Title 24, Part 6 applicable to that occupancy, provided that the applicable mandatory measures in Sections 110 through 139, and 150, are met for each occupancy.

Some residential buildings have areas of other occupancies, such as retail or office, in the same building. An example of this might be a three-story building with two floors of apartments above ground floor shops and offices. The first thing to consider when analyzing the energy compliance of a mixed occupancy building is the type and area of each occupancy type.

Depending on the area of the different occupancies, you may be able to demonstrate energy compliance as if the whole building is residential (the mandatory measures of the actual occupancy still apply). This is allowed if the residential occupancy accounts for greater than 90% of the conditioned floor area of the building (or permitted space).

Note: Mandatory measures apply separately to each occupancy type regardless of the compliance approach used. For example, if complying under the mixed occupancy exception, both residential documentation (MF-1R form) and nonresidential documentation for mandatory measures must be submitted with other compliance documentation.

If the building design does not fit the criteria described above for a dominant occupancy, then each occupancy type must be shown to comply on its own. This may be done by using any of the approved prescriptive or performance methods available for each occupancy type. As a result, documentation for each occupancy type must also be considered separately, and a Certificate of Compliance must be submitted for each occupancy type.

8.3 Subdivisions And Master Plans

8.3.1 Compliance Requirements

Subdivisions often require a special approach to energy compliance, since they generally include one or more basic building or unit plans repeated in a variety of orientations. The basic floor plans, *as drawn,* may also be used in a mirror image or *reversed* configuration.

There are two compliance options for subdivisions. They are:

- Model each individual building, or building condition, separately according to its actual orientation.
- Model all four cardinal orientations for each building or plan type with identical conservation features for no orientation restrictions.

Note: The effective date of the 2001 *Standards* is June 1, 2001. Building energy efficiency standards compliance documentation submitted prior to June 1, 2001 using the multiple Orientation Alternative of §151 (c) shall be used to determine compliance through December 31, 2001.

8.3.2 Individual Building Approach

The most straightforward compliance option for subdivisions is to analyze each individual building in the project separately using any compliance method. This may be practical for subdivisions with only custom buildings, or with only one or two specific orientations for each building plan. This approach requires that each unit comply separately, with separate documentation submitted for each unit plan in the orientation in which it will be constructed.

8.3.3 Multiple Orientation Alternative: No Orientation Restrictions

§151(c)

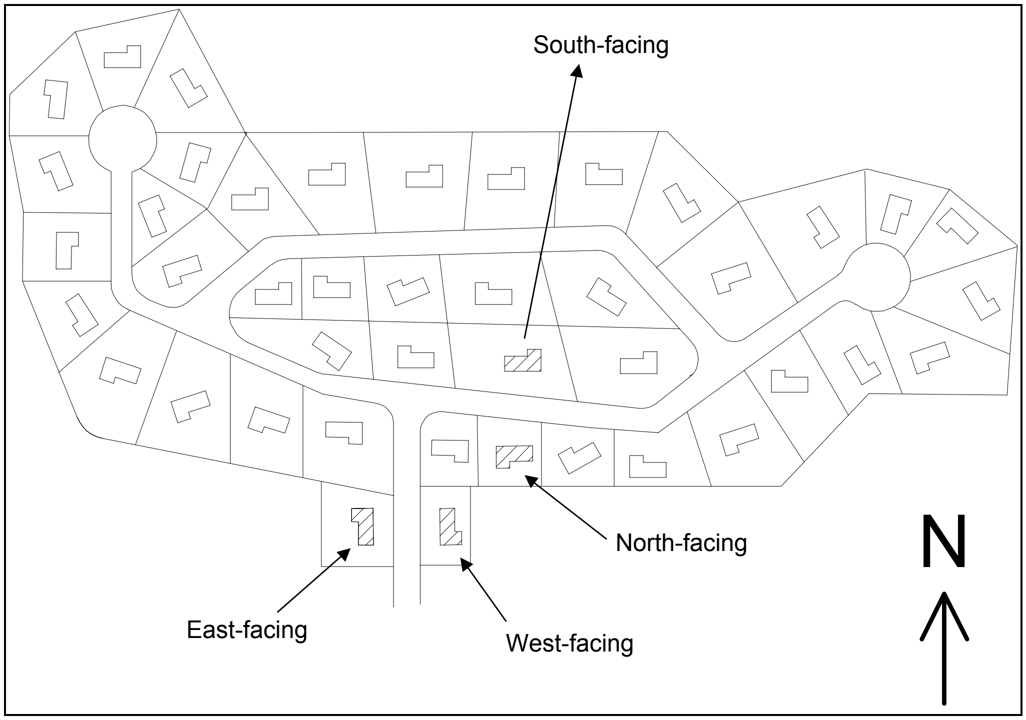
MULTIPLE ORIENTATION ALTERNATIVE to §151(c): A permit applicant may demonstrate compliance with the energy budget requirements of §151(a) and (b) for any orientation of the same building model, if the documentation demonstrates that the building model with its proposed designs and features would comply in each of the four cardinal orientations.

The computer method may be used to demonstrate that a single family dwelling plan or a unit plan in a multi-family building complies regardless of how it is oriented within the same climate zone (Figure 8-2). To assure compliance in any orientation, the annual energy consumption must be calculated in each of the four cardinal orientations: true north, true east, true south and true west. With this option, the buildings must have the identical combination of conservation measures and levels in each orientation and comply with the energy budget in each case.

If a building floor plan is reversed, either the original plans or the reversed plans may be shown to comply in all four cardinal orientations. Multi-family buildings may be analyzed as a whole building using this method or on a unit-by-unit approach at the option of the permit applicant.

Figure 8-2 – Subdivisions and Master Plans Compliance Option

Demonstrate Compliance for Each Cardinal Orientation for Each Basic Model Type



For compliance, submit documentation of the energy budgets for each of the four orientations. In some cases this documentation will be four C-2Rs, while some computer programs generate this information on one form. Only one CF-1R form is required.

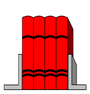
Example 8-3 – Multiple Orientations

A single-family unit plan in Climate Zone 3 has been calculated by an approved computer method to have an energy budget of 27.89 kBtu/ft²-yr. The proposed design is modeled in all four orientations and no variation in any conservation measure. The following predicted energy use is calculated:

Front North	=	24.65 kBtu/ft²-yr
Front East	=	26.41 kBtu/ft²-yr
Front South	=	27.07 kBtu/ft²-yr
Front West	=	27.83 kBtu/ft²-yr

Since the energy consumption is less than 27.89 kBtu/ft2-yr in all cases, the unit plan may be constructed in any orientation within Climate Zone 3.

8.4 Fenestration Products



§101(b))

The following definitions are from §101 of the *Standards*.

DUAL-GLAZED GREENHOUSE WINDOWS are a type of dual-glazed fenestration product which adds conditioned volume but not conditioned floor area to a building.

EXTERIOR DOOR is a door through an exterior partition that is opaque or has a glazed area that is less than or equal to one-half of the door area. Doors with a glazed area of more than one-half of the door area are treated as a fenestration product.

FENESTRATION PRODUCT is any transparent or translucent material plus any sash, frame, mullions, and dividers, in the envelope of a building, including, but not limited to:

windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one-half of the door area.

SKYLIGHT is glazing having a slope less than 60 degrees from the horizontal with conditioned space below.

SOLAR HEAT GAIN COEFFICIENT (SHGC) is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

WINDOW is glazing that is not a skylight.

Below is a discussion of how fenestration works, how features of the product affect its rated efficiencies (U-factor and SHGC), terminology and general compliance information. In addition:

- Certification, labeling and mandatory requirements for fenestration products are included in Chapter 2.
- Additions and alterations compliance issues related to fenestration are discussed in Chapter 7.
- Fenestration topics related to prescriptive and computer compliance are found in Chapters 3 and 5.

8.4.1 Fenestration Categories

§101(b))

There are three main categories of fenestration products – field-fabricated fenestration, manufactured fenestration, and site-built fenestration. The following definitions of fenestration categories are from §101(b) of the *Standards*:

FIELD-FABRICATED FENESTRATION PRODUCT [OR EXTERIOR DOOR] is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

MANUFACTURED FENESTRATION PRODUCT is a fenestration product typically assembled before delivery to a job site. A "knocked-down" or partially assembled product sold as a fenestration product must be considered a manufactured fenestration product and meet the rating and labeling requirements for manufactured fenestration products.

SITE-ASSEMBLED FENESTRATION includes both field-fabricated fenestration and site-built fenestration.

SITE-BUILT FENESTRATION PRODUCTS are fenestration products designed to be field glazed or field assembled units comprised of specified framing and glazing components. Site-built fenestration is eligible for certification under NFRC 100-SB, and may include both vertical glazing and horizontal glazing.

8.4.2 Energy Impact

Windows, glazed doors and skylights have a significant impact on energy use in a home. They account for up to 50% of residential space-conditioning energy. The size, orientation and types of installed fenestration products can dramatically affect the overall energy performance of a house. If designed properly, windows can add heat to a space in the winter, lowering heating bills.

Fenestration products can be responsible for up to 50% of heat loss in the winter and up to 50% of the heat gain in the summer. The U-factor and the SHGC both contribute to maintaining overall thermal comfort and energy performance throughout the year. Properly operating shading year round curtails heat gain in the summer, but reduces the need for heating in the winter. Likewise, the U-factor is important in reducing conductive heat gain in hot climates.

Fenestration performance is related to U-factor and SHGC:

- U-factor is a measure of how much heat travels through a fenestration product. *The lower the U-factor, the more energy efficient the product*.
- SHGC is a measure of the relative amount of heat gain from sunlight that passes through a fenestration product. *The lower the SHGC, the better fenestration is able to keep out solar radiation. The higher the SHGC, the better the window fenestration is able to let in solar radiation.*

The U-factor and the SHGC both contribute to winter and summer overall thermal comfort and energy performance. Several parameters control the performance of fenestration products. These include:

- Frame materials, design and configuration (including cross-sectional characteristics)
- Number of panes of glazing
- Gap width (i.e., the distance between panes)
- Window type (i.e., casement versus double hung)
- Glass surface coatings and/or films
- Gas infill type (i.e., type of gas filling the space between panes of glass)
- Spacer material (i.e., the type of material separating multiple panes of glass)

Fenestration is usually framed in wood, aluminum, vinyl or composites of these. Frame materials such as wood and vinyl are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element as compared with similar units that have no such conductive thermal barriers.

Dual glazing offers opportunities for improving performance beyond the dimension of the air space between panes. For example, special materials that reduce emissivity of the surfaces facing the air space, including so-called low-e (low-emissivity) or other coatings, improve the thermal performance of fenestration products through the glass. Fill gases other than dry air – such as carbon dioxide, argon or krypton – also improve thermal performance.

8.4.3 Fenestration Terms

The following is a brief description of some common terms associated with fenestration products:

Center of Glass U-factor: The U-factor measured only through the glass more than 2.5 inches from dividers or the edge of the glass.

Dividers (Muntins): Elements that actually or visually divide different lites of glass. These may be true divided lites, between the panes, and/or applied to the exterior or interior of the glazing.

Edge of Glass: The area of glazing within 2.5 inches of the spacer.

Frame Types:

- Thermal Break: Metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl, with a significantly lower conductivity.
- Non-metal: Vinyl, Wood or Fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics.

Gap Width: The distance between glazings in multi-glazed systems (e.g., dual or triple glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit width which is measured from outside surface to outside surface.

Gas Infill: Air, argon, krypton, carbon dioxide, SF6 or a mixture of these gases, placed in the space between the panes of dual or triple glazing.

Grilles: See Dividers.

IG Unit: Insulating glass unit. An IG unit includes the glazings, spacer(s), films (if any), gas infills and edge caulking.

Lights or Lites: a layer of glazing material, especially in a multi-layered IG unit.

Low E Coating (low emissivity metallic coating): A transparent metallic coating applied to glazing that reduces its emissivity, and therefore improves its thermal performance. Low E glazing has a better (lower) U-factor than standard glazing. Many low-e coatings also lower the SHGC. Types of Low E coatings include:

- **Soft Coat**: A sputter applied coating sprayed on at a high temperature. These coatings are usually susceptible to degradation (i.e., oxidation) from contact through handling and storing, but generally provide a lower emissivity, and therefore better thermal performance, than hard coatings.
- **Hard Coat:** Low emissivity metallic coatings applied pyrolytically at or near the melting point of the glass so that it bonds with the surface layer of glass. Hard coatings are not subject to oxidation or scratching as the soft coatings are, and new hard coat technologies provide performance very close to that of the soft coatings.

Mullion: Vertical framing member separating adjoining windows or doors.

Muntins: See Divider.

Spacer: A material that separates multiple panes of glass in an insulating glass unit. Types of spacers include:

- **Aluminum**: Metal channel that is used either against the glass (sealed along the outside edge of the insulated glass unit), or separated from the glass by one or more beads of sealant.
- **"Insulating"**: Non-metallic, fairly non-conductive materials, usually rubber compounds.
- **Others:** Wood, fiberglass and composites.

Suspended Films: Plastic films, stretched between the elements of the spacers between panes of glazing, which act as radiant reflectors to slow the heat loss from the interior to the exterior.

8.4.4 U-factor Certification

The U-factor is the total amount of heat that flows through a fenestration product at a given difference in temperature between the interior and exterior surfaces, including the frame, edge of glass and muntins, in Btu/hr-ft^2-ºF. As required by §116 of the *Standards*, there are two procedures for establishing the U-factor of fenestration products:

- The National Fenestration Rating Council NFRC-100-91 (1991) or NFRC 100 (1997); or
- Default U-factors (see Table 2-2).

Estimating the rate of heat transfer through framing elements of a fenestration product is complicated by the variety of frame configurations for operable windows, the different combinations of materials used for sash and frames, and the difference in sizes available in various applications. The NFRC rating system makes the differences uniform, so that an entire fenestration product line is assumed to have only two typical sizes, one for residential and one for nonresidential. The NFRC rated U-factor may be obtained from a directory of certified fenestration products, directly from a manufacturer's listing in product literature, or from the product label.

Note: Each general type of fenestration product (e.g., double wood-frame Low-E or double metal-frame thermal break) has within it a wide range of U-factors. Therefore, it is impossible to predict the U-factor of a specific product without obtaining the NFRC U-factor rating. Consult the NFRC's fenestration product directory or the manufacturers listed NFRC U-factor ratings carefully when selecting a U-factor to use in compliance calculations.

8.4.5 U-factor for Product Specification Compliance/ Plan Check

When performing compliance calculations and preparing documentation, consult a directory of fenestration products which contains the certified U-factor ratings. One such directory is available from NFRC.

If the exact make and model number of the fenestration products to be installed is not known, there are a few options:

- Look up the U-factors for a number of the products most likely to be installed, and use the highest value of those products. Whichever fenestration product is then installed will comply with the U-factor used in the calculation.
- Specify a particular product and state "or equivalent." In this approach, the builder or installer must understand that the U-factor of the installed product must match, or be less than, the U-factor specified in the compliance documentation.
- Use the appropriate default U-factor from Table 1-D of §116 of the *Standards* (see Chapter 2). The disadvantages of this approach are that:
  (a) There is no guarantee that a selected product will have the same or better performance than the U-factor assigned to that generic type; or,
  (b) The U-factor in the table may be much higher than the actual installed U-factor so that additional efficiency measures may be required for compliance.

8.4.6 SHGC Certification

The SHGC is the measure of how well a fenestration product limits solar heat gain entering the space through the fenestration. This value includes the effects of the frame which also effect how much solar heat enters the building.

As required by §116 of the *Standards*, there are two procedures for establishing the SHGC of fenestration products:

- The National Fenestration Rating Council NFRC 200 (1995); or,
- Default SHGC values (see Chapter 2).

SHGC values are between 0 and almost 1, with 1.00 representing no ability to limit solar heat gain. The lower the SHGC, the less solar heat is transmitted through the fenestration product.

For a full explanation of shading, SHGC and shading calculations including the effects of framing divider factors, interior blinds and exterior sunscreens, see *Shading* in the *Glossary*.

Note: Low-e coatings lower the SHGC in addition to reducing heat loss, but there is no direct relationship between emissivity and SHGC. For example, a dual glazed unit with an emissivity of 0.22 may have an SHGC of 0.73 – nearly identical to clear dual glazing - or it may have an SHGC of 0.60, much lower than clear dual glazing.

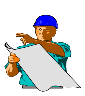
8.4.7 SHGC Specification Compliance/ Plan Check

When performing compliance calculations and preparing documentation, consult a directory of fenestration products that contains the certified SHGC ratings. One such directory is available from NFRC.

If the exact make and model number of the fenestration products to be installed is not known, there are a few options:

- For those climate zones that have an SHGC requirement of 0.40 look up the SHGC value for a number of products most likely to be installed, and use the highest value of those products. Whichever fenestration product is then installed will comply with the SHGC value used in the calculation.
- Specify a particular product and state "or equivalent." In this approach, the builder or installer must understand that the SHGC value of the installed product must match or be less than the SHGC value specified in the compliance documentation.
- Use the appropriate default SHGC value from Table 1-E of §116 of the *Standards* (see Chapter 2). The disadvantages of this approach are that:
    - There is no guarantee that a selected product will have the same or better performance than the SHGC assigned to that generic type; or,
    - The SHGC value in the table may be much higher than the actual installed SHGC. This may cause the actual energy use to be either higher or lower, depending on climate and the interaction of the fenestration shading with overhangs and building orientation, and may result in additional efficiency measures being required for compliance.

8.4.8 Fenestration Products Construction



The fenestration product installer needs to understand the required U-factors and product SHGC values for the specific project, based on the compliance documentation such as the Certificate of Compliance (CF-1R). The installer should check the documentation to insure that the products have the temporary label on the center of the glazing which meets the compliance requirements.

The U-factor for compliance with the residential standards is the "AA" size. Make sure the "AA" size U-factor is the same as, or less than, the U-factor used in the compliance documentation. The temporary label must remain on the product until the field inspector has inspected it.

See Chapter 1 for a complete discussion of Installation Certificate (CF-6R form) and the responsibility for completing this form as required by §10-103 (Administrative Regulations)

8.4.9 Bay Windows

Bay windows may either have a unit NFRC rating (i.e. the rating covers both the window and all opaque areas of the bay window), an NFRC rating for the window only, or no NRFC rating. Non-rated bay windows may or may not have factory-installed insulation.

For bay windows that come with an NFRC rating for the entire unit determine compliance based on the rough opening area of the entire unit, applying the NFRC U-factor and SHGC. If the unit U-factor and SHGC do not meet the Package requirements, the project must show compliance using the Performance approach.

Bay windows that do not come with a rating for the entire unit (where there are multiple windows to make up the bay), and come with factory installed, or field installed, insulation must comply accounting for the performance characteristics of each component separately. Opaque portions must meet the Mandatory Measures minimum insulation requirements (i.e. R-19 ceiling, R-13 walls, R-13 floor). For prescriptive compliance, the opaque portion must either meet the minimum insulation requirements of the Packages for the applicable climate zone or be included in a weighted average U-factor calculation of an overall opaque assembly that does meet the Package requirements. For the windows, the U-factor and SHGC values may be determined either from an NFRC rating, or by using default values. If the window U-factor and SHGC meet the Package requirements, the bay window complies prescriptively (if overall building fenestration area meets prescriptive compliance requirements). Bay window fenestration area is based on each individual window in the bay window. If the bay window does not meet Package requirements, the project must show compliance under the Performance approach. Bay window fenestration area and orientation in the performance approach is based on each individual window in the bay window.

8.5 Wood Space Heating

§101(b))

WOOD HEATER is an enclosed wood burning appliance used for space heating and/or domestic water heating, and which meets the definition in Federal Register, Volume 52, Number 32, February 18, 1987.

Neither a penalty nor a credit is offered for qualifying wood space heating systems. For compliance with the prescriptive method, you can assume that the heating system has the same performance as Package D, e.g. a gas furnace with an AFUE of 78%, with sealed R-4.2 ducts in the attic. The other measures in the prescriptive package have to be met. For compliance with the performance method, the methodology is described in Chapter 5 (see Table 5-4).

An exceptional method establishes guidelines for use of wood heaters with the *Standards*. The following eligibility criteria apply.

A. The building department having jurisdiction must determine that natural gas is not available;

Note: Liquefied petroleum gas, or propane, is not considered natural gas.

B. The local or regional air quality authority must determine that their authorization of this exceptional method is consistent with state and regional ambient air-quality requirements pursuant to Sections 39000 to 42708 of the California Health and Safety Code;

C. The wood heater must be installed in a manner which meets the requirements of all applicable health and safety codes, including, but not limited to, the requirements for maintaining indoor air quality of the *Uniform Mechanical Code*, in particular those homes where vapor barriers are installed (see Chapter 2);

D. The wood heater must meet the EPA definition of a wood heater as defined in the Federal Register, Vol. 52, No. 32, February 18, 1987 (see below);

E. The performance of the wood heater must be certified by a nationally recognized agency and approved by the building department having jurisdiction, to meet the performance standards of the EPA;

F. The rated output of the wood heater must be at least sixty percent (60%) of the design heating load, using calculation methods and design conditions as specified in §150(h) of the *Standards* (see Chapter 2)*;*

G. At the discretion of the local enforcement agency, a backup heating system may be required to be installed and be designed to provide all or part of the design heating load, using calculation methods and design conditions as specified in §150(h) of the *Standards*;

H. The wood heater must be located such that transfer of heat from the wood heater is effectively distributed throughout the entire residential unit or must be used in conjunction with a mechanical means of providing heat distribution throughout the dwelling.

   Habitable rooms separated from the wood heater by one free opening of less than 15 square feet or two or more doors must be provided with a positive heat distribution system, such as a thermostatically controlled fan system. Habitable rooms do not include closets or bathrooms.

   Wood heaters on a lower level are considered to heat rooms on the next level up, provided, they are not separated by two or more doors.

I. The wood heater must be installed according to manufacturer and local enforcement agency specifications and must include instructions for homeowners that describe safe operation;

J. The local enforcement agency may require documentation that demonstrates that a particular wood heater meets any and all of these requirements.

Equipment Criteria

The federal register includes minimum criteria for wood heaters, established by the Federal Environmental Protection Agency. This criteria defines a wood heater as:

> ... an enclosed, wood burning appliance used for space heating, domestic water heating, or indoor cooking that meets all of the following criteria:
>
> 1. An air-to-fuel ratio averaging less than 35 to 1,
> 2. Firebox volume less than 20 cubic feet,
> 3. Minimum burn rate less than 5 kilogram/hour (11.0 lbs/hr), and
> 4. Maximum weight of less than 800 kilograms (1762 lbs).

The federal rules explicitly exclude furnaces, boilers and open fireplaces, but include wood-heater inserts.

The Energy Commission's exceptional method for wood heaters with any type of backup heating is available in areas where natural gas is not available. If the required eligibility criteria are met, a building with one or more wood heaters may be shown to comply with the *Standards* using one of the following methods:

Note: Duct efficiency credits may *not* be taken, as the combined wood heater/backup-heating system is assumed to be equivalent to a 78% AFUE central furnace with R-4.2 ducts in the attic.

Prescriptive Approach

The building envelope conservation measures of any one of the Alternative Component Packages must be installed, and the overall heating system efficiency for the wood heater and its backup-heating system may be assumed to be equivalent to that required by the package.

Performance Approach

A computer method may be used for compliance when a home has wood space heat. There is no credit, however. Both the proposed design and the budget building are modeled with the same system, e.g. with the overall heating system efficiency is assumed to be equivalent to a 78% AFUE central furnace with R-4.2 ducts in the attic and diagnostic testing of the ducts.

Note: If all of the criteria for the wood heat exceptional method is not met, the backup-heating system must be included in the compliance calculations as the primary heat source.

Wood Water Heating

Credit is also available for the use of wood heat with water heating systems. See Wood Stove Boilers in Section 6.6.

Example 8-4 – Pellet Stoves

Question

Are pellet stoves treated the same as wood stoves for the purposes of *Standards* compliance?

Answer

Yes.

Example 8-5 – Wall Installed Wood Stove

Question

If a wood stove is installed in a wall, does it have to meet the fireplace requirements of *Standards* §150(e)?

Answer

No. A wood stove that meets EPA certification requirements does not have to meet any requirements applicable to fireplaces.

8.6 Controlled Ventilation Crawl Space (CVC)

The Energy Commission has approved an exceptional method for analyzing the energy impact of buildings with raised floors, which use foundation wall insulation and have automatically controlled crawl-space vents. The method is available as an option using an approved computer method with unique modeling criteria explained in Section 5.4.12.

The following steps must be taken, *and the approach must be approved by the local building department*, for the raised-floor building to show compliance with the *Standards* under this exceptional method:

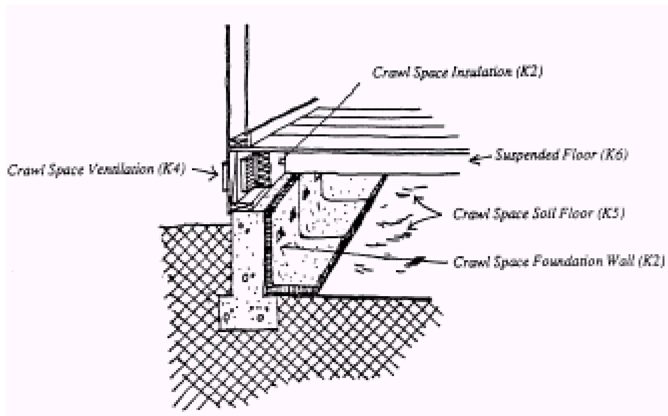
Drainage

Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.

Ground Water And Soils

Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the building officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.

Figure 8-3 – Controlled Ventilation Crawl Space



Ventilation

All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.

Perimeter Insulation

Foam Plastic Insulating Materials

Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:

- Fire Safety—*UBC* Section 1712(b)2. Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.
- Direct Earth Contact—Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slab-edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.

Mineral Wool Insulating Materials

- Fire Safety—*UBC* Section 1713(c). "All insulation including facings, such as vapor barriers or breather papers installed within ... crawl spaces ... shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with *UBC*. Standard No. 42-1." In cases where the facing is also a vapor retarder, the facing shall be installed to the side that is warm in winter.
- Direct Earth Contact—Mineral wool batts shall not be installed in direct earth contact unless protected by a vapor retarder/ground cover.

Vapor Barrier (Ground Cover)

A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, shall be laid entirely over the ground area within crawl spaces.

- The vapor barrier shall be overlapped six inches minimum at joints and shall extend over the top of pier footings.
- The vapor barrier should be rated as 1.0 perm or less.
- The edges of the vapor barrier should be turned up a minimum of four inches at the stem wall.
- Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations.
- The vapor barrier must be shown on the plans and installed.

Studies show that moisture conditions found in crawl spaces that have minimal ventilation do not appear to be a significant problem for most building sites provided that the crawl-space floors are covered by an appropriate vapor barrier and other precautions are taken. The Energy Commission urges building officials to carefully evaluate each application of this insulating technique in conjunction with reduced ventilation because of the potential for adverse effects of surface water on crawl-space insulation that could negate the energy savings predicted by the procedure.

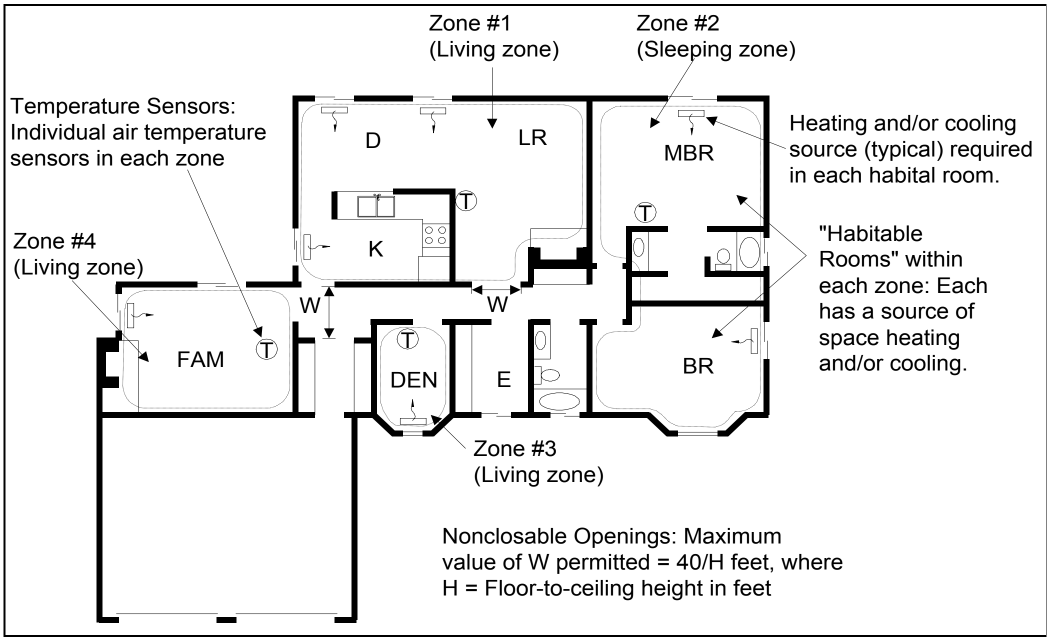
8.7 Zonal Control

An energy compliance credit is provided for zoned heating and air-conditioning systems, which save energy by providing selective conditioning for only those areas of a house that are occupied. A house having at least two zones (living and sleeping) with separate thermostats controlling temperatures in the zones, and with a maximum non-closeable opening of 40 square feet may qualify for this compliance credit. The equipment may consist of one air-conditioning system for the living areas and another system for sleeping areas or a single system with zoning capabilities, set to turn off the sleeping areas in the daytime and the living area unit turned off at night. (See Figure 8-4).

§101(b))

ZONE, SPACE CONDITIONING is a space or group of spaces within a building with sufficiently similar comfort conditioning requirements so that comfort conditions, as specified in 144(b)3 or 150(h), as applicable, can be maintained throughout the zone by a single controlling device.

Figure 8-4 – Zonal Control Example



Note: Although multiple thermally distinct living and/or sleeping zones may exist in a residence, the correct way to model zonal control credit requires only two zones: one living zone and one sleeping zone. All separate living zone components must be modeled as one single living zone, and the same must be done for sleeping zones.

There are unique eligibility and installation requirements that must be met in order for zonal control to qualify under the *Standards*. The following steps must be taken for the building to show compliance with the *Standards* under this exceptional method:

Temperature Sensors. Each thermal zone, including a living zone and a sleeping zone, shall have individual air temperature sensors.

Habitable Rooms. Each habitable room in each zone shall have a source of space heating and/or cooling (if zonal credit for cooling is desired) such as forced air supply registers or individual conditioning units. Habitable rooms shall not include bathrooms, laundry, halls and/or dressing rooms.

Noncloseable Openings. The total noncloseable opening area between adjacent living and sleeping thermal zones (i.e., halls, stairwells or other openings) shall be less than or equal to 40 square feet. All remaining zonal boundary areas shall be separated by permanent floor to ceiling walls and/or fully solid operable doors capable of restricting free air movement when in the closed position.

Setback Thermostats. Each zone shall be controlled by a central automatic dual setback thermostat that can control the conditioning equipment and maintain preset temperatures for varying time periods in each zone independent of the other.

1. Each zone must have automatic dual setback control for heating, and setup control for cooling if cooling, is provided.
2. Thermostat locations in each zone must provide accurate temperature readings of the typical condition in that zone.
3. The control may be switched from heating to cooling mode manually.
4. The control must be programmable by the occupant.

5. For residences using heat pump systems, the automatic setback thermostat must have two-stage heating which incorporates a recovery ramp of other logic that will minimize electric resistance heating.

Forced Air Ducted Systems

1. Each zone must be served by a return air register located entirely within the zone. Return air dampers are not required.
2. Dampers shall be manufactured and installed so that when they are closed, there is no measurable airflow at the registers.
3. The system must be designed to operate within the equipment manufacturer's specifications.
4. Air is to positively flow into, through and out of a zone only when the zone is being conditioned. No measurable amount of supply air is to be discharged into unconditioned or unoccupied space in order to maintain proper air flows in the system.
5. Systems that allow supply air to be by-passed to the return-air system shall be protected against short cycling and excessive temperatures of the space-conditioning equipment, and include necessary controls for efficient, safe and quiet operation.

Example 8-6 – Laundry Room and Bathroom Zoning

Question

In defining the living and sleeping zones for a home with a zonally controlled HVAC system, can laundry rooms and bathrooms (which are not habitable spaces) be included on whichever zone they are most suited to geographically (e.g., a bathroom located near bedrooms)?

Answer

Yes. For computer modeling, include the square footage of any nonhabitable, or indirectly conditioned spaces, with the closest zone.

Example 8-7 – Zonal Control Credit

Question

I have two HVAC systems and want to take zonal control credit. Can the return air for both zones be located in the hallway (living zone)?

Answer

No. Because of the need to prevent mixing of air between the conditioned zone and the unconditioned zone, it is necessary to (1) have the return air for each zone within that zone, and (2) limit any non-closeable openings between the two zones to 40 square feet or less. Unless these criteria, in addition to the other criteria listed in this Chapter can be met, credit for a zonally controlled system cannot be taken.

8.8 Hydronic/Combined Hydronic Space Heating

Hydronic heating is the use of hot water system as a heat source for space-heating system. Figure 8-5 and Figure 8-6 show simple schematics illustrating some of the components in a hydronic-heating system. A hydronic-heating system consists of five parts.

- The water-heating device, usually the water heater.
- A heat delivery device

- Supply and return piping
- One or more pumps
- Controls

Combined hydronic heating refers to the use of a single water-heating device as the heat source for both space and domestic hot water heating. There are two types of combined hydronic systems. One uses a boiler as a heat source for the hydronic space heating system. The boiler also heats domestic water by circulating hot water through a heat exchanger in an indirect-fired water heater.

The other type uses a water heater as a heat source. The water heater provides domestic hot water as usual. Space heating is accomplished by circulating water from the water heater through the space heating delivery system. Sometimes a heat exchanger is used to isolate potable water from the water circulated through the delivery system. Some water heaters have built-in heat exchangers for this purpose.

There are three main types of hydronic delivery systems, which may be used individually or in combination: baseboard or valence convectors, hot water air handlers, and radiant panel heating systems.

- Baseboard/valence convectors are finned tubes that run along the base or top of walls. A metal enclosure conceals the finned tubes. Convectors do not require ducting.
- Air handlers consist of a blower and finned tube coil enclosed in a sheet metal box, and may be ducted or non-ducted. Air handlers may also include refrigerant coils for air conditioning.
- Radiant panels may be mounted on or integrated with floors, walls, and ceilings. Radiant floor panels are most typical. Tubing for radiant floor systems may be:
- Embedded in a concrete floor slab
- Installed over the top of wood sub-floor and covered with a concrete topping
- Installed over the top of wood sub-floor in between wood furring strips
- Installed on the underside surface of wood sub-floor

In the latter two types of installations aluminum fins are typically installed to spread the heat evenly over the floor surface, and to reduce the temperature of the water required. All hydronic systems use one or more pumps to circulate hot water. Pumps are controlled directly or indirectly by thermostats, or by special outdoor reset controls.

Complete a DHW-5 worksheet for any project that includes a hydronic space-heating system. This worksheet should accompany all applicable water-heating compliance worksheets. The DHW-5 worksheet is used to determine the effective AFUE for storage gas water heaters and the effective HSPF for storage electric and heat pump water heaters used to supply energy for the combined hydronic space- and water-heating system.

Figure 8-5 – Hydronic Heating Heat Distribution Devices

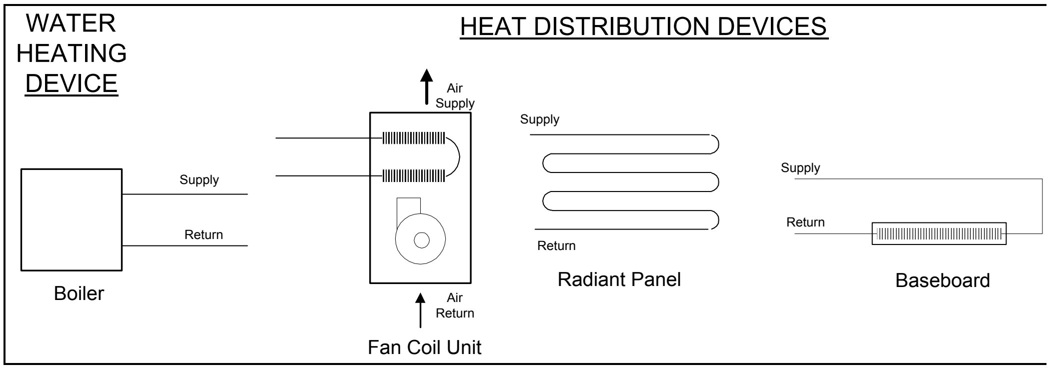
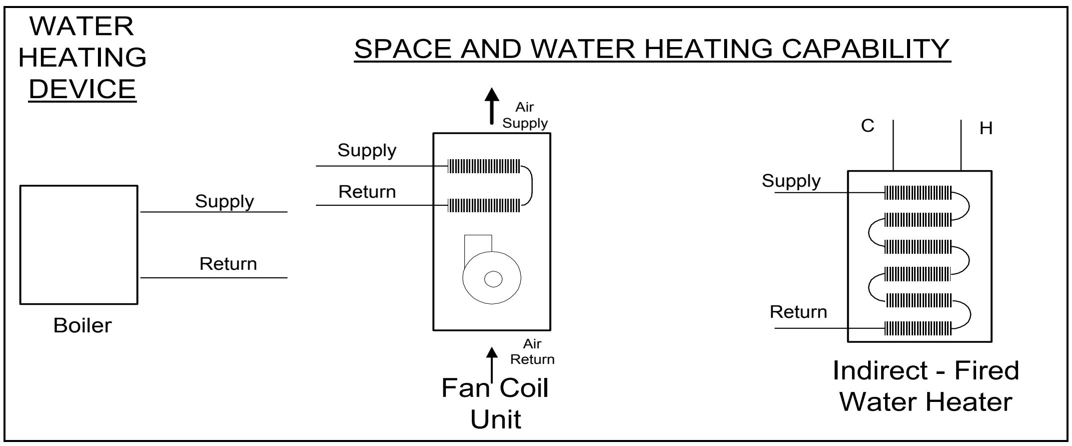


Figure 8-6 – Space and Water Heating Capability



Dedicated Hydronic Systems

Dedicated hydronic systems use separate water heating devices for space heating and water heating. For showing compliance of dedicated hydronic systems, the AFUE (for boilers and gas water heaters) or HSPF (for heat pumps), as determined in Section 6.5 (DHW-5), is used. This AFUE or HSPF value is used in the packages or for showing compliance with an energy budget. For water-to-water heat pumps use the following formula: HSPF = (3.2 x COP) – 2.4. Separate compliance for the water-heating system is also required.

Combined Hydronic Space- and Water-Heating Systems

When the hydronic space-heating system serves the additional function of providing domestic hot water (or vice versa), the system is analyzed for its water heating performance as if the space heating function were separate. In other words, treat any hydronic system used for water heating the same as any other water-heating system. Input the correct water heater type, auxiliary input credit (if any) and specify the distribution system.

Compliance

An “effective” AFUE or HSPF rating is used to establish space-heating system efficiency. Refer to Section 6.5 for an explanation of how both water-heating and space-heating system characteristics are accounted for, including the calculation of an Effective AFUE or Effective HSPF rating on the DHW-5 form.

Compliance for a hydronic or combined hydronic-heating system consists of four parts:

1. The water-heating device is typically a boiler or hot water heater, but may be a heat pump.
2. A heat delivery device will be a fan coil, baseboard or radiant panel. Hot water baseboards and radiant panels are normally used for space heating only, and may provide compliance credits since there are no ducts.

3. Supply and return piping.
4. One or more pumps.

Radiant Floor System

One type of radiant panel distribution system is the radiant floor system, where space heating hot water pipes are placed in a concrete slab floor or into a lightweight concrete topping slab laid over a raised floor. These hydronic radiant floor systems in concrete slabs require insulation to be provided between the heated portion of the slab and the outdoors. This insulation may either be slab edge insulation installed from the level of the top of the slab, down 16" or to the frost line, whichever is greater (insulation may stop at the top of the footing, where this is less than the required depth), or heated slab perimeter insulation installed down from the top of the slab and wrapping under the slab for a minimum of 4 feet toward the middle of the slab. The required insulation value for each of these insulating methods is shown in Table 8-1. For performance compliance, the model must assume no insulation is installed, when the insulation levels shown in Table 8-1 are installed. For insulation levels greater than those shown in Table 8-1, the insulation value greater than the value shown in Table 8-1 may be entered into the computer programs for determining the benefits of the additional insulation. Local conditions (such as a high water table) may require special insulation treatment in order to achieve satisfactory system performance and efficiency. To determine the need for additional insulation, follow the recommendations of the manufacturer of the hydronic tubing being installed. Where there is a danger of termite infestation, install termite barriers, as required, to prevent hidden access for insects from the ground to the building framing.

Note: The slab edge insulation required in Table 8-1 is treated as an energy neutral feature. It is not assumed in compliance calculations for credit. R-0 slab edge insulation must be assumed in climate zones 1-15. R-7 must be assumed in climate zone 16.)

Slab edge insulation applied to basement or retaining walls (with slab below grade) should be installed so that insulation starts at ground level and extends down the required distance.

Table 8-1 – Slab Insulation Requirements for Heated Slabs

Climate Zone	***Location of Insulation***	***Orientation of Insulation***	***Insulation R-Factor***	***Installation Criteria***
1-15	Outside edge of slab, either inside or outside the foundation wall	Vertical	5	From the level of the top of the slab, down 16" or to the frost line, whichever is greater. Insulation may stop at the top of the footing, where this is less than the required depth. For below grade slabs, vertical insulation shall be extend from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or frost line whichever is greater.
16	Outside edge of slab, either inside or outside the foundation wall	Vertical	10	From the level of the top of the slab, down 16" or to the frost line, whichever is greater. Insulation may stop at the top of the footing, where this is less than the required depth. For below grade slabs, vertical insulation shall be extend from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or frost line whichever is greater.
1-15	Between heated slab and outside foundation wall	Vertical and Horizontal	5	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plan view.
16	Between heated slab and outside foundation wall	Vertical and Horizontal	10 vertical and 7 horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plan view.

Radiant Floor System/Slab Edge Insulation

When space heating hot water pipes are set into a concrete slab floor, slab edge insulation from the level of the top of the slab, down 16" or to the frost line, whichever is greater (insulation may stop at the top of the footing, where this is less than the required depth), or insulation installed down from the top of the slab and wrapping under the slab for a minimum of 4 feet toward the middle of the slab is required. When space heating hot water pipes are set into a lightweight concrete topping slab laid over a raised floor, any portions of the topping slab directly adjacent to an exterior wall or a retaining wall must have an insulation barrier as shown in Table 8-1 between the topping slab and the exterior of the wall and insulation installed wrapping under the lightweight topping for a minimum of 4 feet toward the middle of the slab. Raised floor insulation that meets the mandatory minimums for wood floor assemblies meets the requirement for insulation wrapping under the lightweight topping slab. Slab edge insulation applied to basement or retaining walls (with slab below grade) must be installed so that insulation starts at or above ground level and extends down the required distance.

Compliance is affected by:

- Water heater or boiler efficiency
- Length of pipe
- Pipe insulation thickness
- Rated input
- Pump Watts (for storage electric).
- Hot water baseboards and radiant panels may provide compliance credits since there are no ducts.
- Slab edge insulation as shown in Table 8-1 must be installed for a hydronic radiant slab floor heating system.

The system will consist of:

1. Water heating device—water heater or boiler.
2. A heat delivery device—fan coil, baseboard or radiant panel.
3. Supply and return piping.
4. One or more pumps.
5. Controls required to operate the system—may include a fan and/or pump relay, distribution system zone valves, boiler return water temperature control, and a delivery water temperature controller.

Example 8-8 – Dedicated Hydronic-heating System

Question

My client wants a dedicated hydronic-heating system (space heating only), but a few things are unclear: (1) What piping insulation is required? (2) Can I use any compliance approach? (3) Do I have to insulate the slab with slab edge insulation? and (4) What special documentation must be submitted for this system type?

Answer

(1) The supply lines not installed within a concrete radiant floor must be insulated in accordance with §150(j)—R-4 on pipes that are 2 inches or less in diameter, R-6 for pipes greater than 2 inches in diameter.

(2) You can use any compliance approach; however, when using a prescriptive compliance approach, the AFUE or HSPF (as determined on the DHW-5) must meet the minimum efficiency of the selected Alternative Component Package. NOTE: CALRES requires that a boiler be used as the water heating device for a dedicated hydronic system.

(3) The slab edge insulation shown in Table 8-1 is only required when the distribution system is a radiant floor system (pipes in the slab). When this is the case the insulation values shown in Table 8-1 are mandatory measures (no modeling or credit).

(4) A DHW-5 worksheet is used to determine the system efficiency (AFUE or HSPF) and must be submitted with other compliance documentation for prescriptive compliance. As noted in Chapter 6, Table 6-2, approved programs perform the water heating calculations internally, so the DHW forms do not need to be submitted.

Example 8-9 – Slab edge Insulation Requirements

Question

What are the slab edge insulation requirements for a hydronic-heating system with the hot water pipes in the slab?

Answer

The requirements for slab edge insulation can be found in §150(l) and §151(f)1 of the standards and Chapters 2 and 8.

Material and installation specifications:

- Insulation values as shown in Table 8-1
- Protected from physical damage and ultra-violet light deterioration
- Water absorption rate no greater than 0.3% (ASTM-C-271)
- Water vapor permeance no greater than 2.0 per/inch (ASTM-E-96-90)

Modeling assumption:

Do not model or calculate benefits for the insulation levels shown in Table 8-1; they are mandatory requirement for this type of heating system. Instead assume R-0 in climate zones 1 through 15, or R-7 in climate zone 16.

8.9 Evaporative Cooling

Credit for evaporative coolers is allowed in all low-rise residential buildings. Evaporative coolers provide cooling to a building by either direct contact with water (direct evaporative cooler), or a combination of a first stage heat exchanger to pre-cool building air temperature and a second stage with direct contact with water (indirect/direct evaporative cooler).

When selecting evaporative cooling, the following characteristics should be considered:

- Direct evaporative coolers in climates that are both hot and humid may result in uncomfortable indoor humidity levels.
- Indirect/direct evaporative coolers do not increase indoor humidity as much as direct systems, and would be unlikely to produce uncomfortable indoor humidity levels, even in hot, humid areas.
- Evaporative coolers may not reduce indoor temperatures to the same degree as air conditioning.

Evaporative coolers may be used with any compliance approach. Using a performance approach, credit is provided in all low-rise residential buildings. To take the credit, assume that there is a standard central air conditioner (with R-4.2 ducts in the attic) with a SEER rating of 11.0 for direct systems and 13.0 for indirect/direct systems. The same SEERs can be used for evaporative coolers installed with or without backup air conditioning [see multiple HVAC systems in Chapter 5 (computer compliance)].

Ducts from evaporative coolers do not have to be sealed per the prescriptive requirements [§151 (f) 10.], as long as they are not also used by conventional heating or cooling systems.

To receive credit at the efficiencies listed above, the evaporative cooling system must meet the following requirements:

Eligibility and Installation Criteria

1. Evaporative cooler ducts must satisfy all requirements that apply to air conditioner ducts except for diagnostic testing for duct leakage when there is a dedicated duct system for evaporative cooling only.
2. Thermostats are required. If air conditioning is installed in conjunction with an evaporative cooler a two-stage thermostat with time lockout is required.
3. Automatic relief venting must be provided to the building.
4. Evaporative coolers must be permanently installed. No credits are allowed for removable window units.
5. Evaporative coolers must provide minimum air movement at the minimum stated air delivery rate certified with the tests conducted in accordance with the Air Movement and Control Association (AMCA) Standard 210 (see Table 8-2 below).

Table 8-2 – Minimum Air Movement Requirements for Evaporative Coolers Minimum Air Movement[1]

Climate Zones	***Direct (cfm ft²)***	***Indirect/Direct (cfm ft²)***
1 - 9	1.5	1.2
10 - 13	3.2	1.6
14 - 15	4.0	2.0
16	2.6	1.3

[1] If backup air conditioning is installed, the minimum air movement for all climate zones is 1.0 cfm/sf.

8.10 Geothermal (Ground Source) Heat Pump

A geothermal or ground source heat pump uses the earth as a source of energy for heating and as a sink for energy when cooling. Some systems pump water from an aquifer in the ground and return the water to the ground after transferring heat from or to the water. A few systems use refrigerant directly in a loop of piping buried in the ground. Those heat pumps that use either a water loop or pump water from an aquifer have efficiency test methods that are accepted by the Energy Commission. These efficiency values are certified to the Energy Commission by the manufacturer and are expressed in terms of heating Coefficient of Performance (COP) and cooling Energy Efficiency Ratio (EER).

To determine compliance with the residential standards, the COP and EER must be converted to HSPF and SEER

When equipment is not tested for SEER, the EER may be used in place of the SEER. When heat pump equipment is not tested for HSPF, calculate the HSPF as:

Equation 8-1

$$HSPF = (3.2 \times COP) - 2.4$$

The efficiency of geothermal heat pump systems is dependent on how well the portion of the system in the ground works. Manufacturer's recommendation must be followed carefully to assure that the system is appropriately matched to the soil types and weather conditions. Local codes may require special installation practices for the ground-installed portions of the system. Verify that the system will meet local code conditions before choosing this type of system to meet the *Standards*.

8.11 Log Homes

Log homes are an alternative construction type used is some parts of the state. Log home companies promote the aesthetic qualities of solid wood construction and can "package" the logs and deliver them directly to a building site. Some companies provide log wall, roof and floor systems with special insulating "channels" or other techniques to minimize the effect of air infiltration between log members and to increase the thermal benefit of the logs alone.

Uninsulated eight-inch solid logs can have an overall thermal resistance equivalent to R-11 insulation (the type of wood is a factor in the R-value). If the wood type of the log is not known, contact the manufacturer to obtain this information.

Note: The mandatory requirement for a minimum of R-13 wall insulation does not apply to unframed walls (e.g., log walls, mass walls).

The thermal mass effects of log home construction can be accounted for within the computer compliance approach (Chapter 5) or prescriptive package C (Chapter 3). Although log walls are not required to be insulated to the level of a framed wall, the effects of the thermal mass (interior and exterior) can compensate for the lack of insulation.

In the computer methods, thermal mass is accounted for when the building envelope is modeled with the specific type of wood (cedar, pine or fir) found in the construction materials section of the computer program. The computer determines the heat capacity of the solid wood/log based upon the wood type and its thickness.

See Chapter 5 and the compliance supplement for the specific computer method being used.

Air infiltration between log walls can be considerably different between manufacturers depending upon the construction technique used. For purposes of compliance, infiltration is always assumed to be equivalent to a wood frame building.

8.12 Straw Bale Construction

In 1995, the California Legislature passed AB1314, a bill that authorizes all California jurisdictions to adopt building codes for houses with walls constructed of straw bales. The bill provided guidelines for moisture content, bale density, seismic bracing, weather protection, and other structural requirements. In order to demonstrate compliance with the *Standards* the Energy Commission, in conjunction with other research and testing facilities, determined the thermal properties needed for compliance. The thermal mass benefit of straw bale construction can only be credited through the use of the computer performance compliance approach by modeling straw bale construction using the heat storage and heat capacity characteristics of the straw bales given below.

Straw bales that are 23 inches by 16 inches are assumed to have a thermal resistance of R-30, whether stacked so the walls are 23 inches wide or 16 inches wide. (Performance data on other sizes of bales was not available at the time of publication of this *Manual*.) The minimum density of load bearing walls is 7.0 pounds per cubic foot, this value or the actual density may be used for modeling straw bale walls in computer compliance approaches. Specific heat is set to 0.32 Btu/lb/°F. Volumetric heat capacity (used in some computer programs) is calculated as density times specific heat (at a density of 7 lb/ft^3 the volumetric heat capacity is 2.24 Btu/ft^3/°F.

The minimum dimension of the straw bales when placed in the walls must be 22 inches by 16 inches. There are no restrictions on how the bales are stacked.

Due to the higher resistance to heat flow across the grain of the straws, a bale laid on edge with a nominal 16 inch horizontal thickness has the same R-Value (R-30) as a bale laid flat. When the bale is laid flat the nominal horizontal wall thickness is 23 inches but the heat flows along the grain of the straws resulting in the same R-30 thermal resistance for the bale. Thermal performance data on other sizes of bales was not available at the time of publication of this *Manual*.

8.13 Radiant Barriers

See 3.4 Radiant Barriers.

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